Airplane Engine Encyclopedia

An Alphabetically Arranged
Compilation of All Available Data
on the World's Airplane Engines

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for the United States Air Service

First Edition

THE OTTERBEIN PRESS
Dayton, Ohio

Preface

THE Airplane Engine Encyclopedia is intended to serve as a reference book for those who are interested in any phase of airplane engine design and construction. Owing to the large number of airplane engines which have already appeared, the descriptions are necessarily condensed and contain only the important and distinguishing characteristics that are known of each one. Some references are of nothing more than historic interest; however, at the time of going to press, no engine is known to the author to which reference has not been made.

The widely distributed sources of such information are usually inaccessible to the average engineer owing to their international derivation, being in many cases unknown; and when known, extremely cumbersome for reference purposes. The majority of airplane engines have been described in various aeronautical works and periodicals, but often as a basis for a discussion on design. This has been purposely avoided in this work since the subject will be very thoroughly treated in subsequent volumes.

Much repetition of experiment on identical types or details occurs through lack of knowledge in regard to the efforts of other workers on similar lines, and results in a waste of inventive skill which might otherwise be turned to more constructive ends. This work will be justified if it in any way should direct engine development along useful lines, and assist in avoiding methods that have long since proved unsound.

The author cannot, of course, be held responsible in all cases for the reliability of the sources of the information used, and it is inevitable that some types, particularly those experimented with more or less privately, have been left unmentioned. The readers are therefore invited to submit such

information as they possess on any engine that has not been included, or too briefly described, and direct attention to the errors which may have occurred so that the necessary additions and corrections can be made in subsequent editions that may be published in due course should conditions warrant it.

References to the source of information are omitted on the score that a number of these descriptions have repeatedly appeared and some are too brief to be of value. In instances where it has been impossible to obtain data from the manufacturer or other original sources, the material has been drawn from the following books and periodicals:

Aero Engines ....G. A. Burls.
Aeronautical Engines ....Kean.
Aeronautical Motor ....Hayward.
Aviation Engines ....Pagé
Elementary Aeronautics ....Thurston.
Flugmotoren ....von Hermann Dorner and Walther Isendahl

Jane's Aircraft Year Book (1917).
Jane's Aircraft Year Book (1919).
Luftfahrzurgbau...................Dr. Fritz Huth

Aerial Age.
Aero and Hydro.
Aeronautics.
Automotive Industries.
Aviation.
Flight.
L'Aeronautique.
Motorwagen.
The Aeroplane.
The Automobile Engineer.

In conclusion the author wishes to thank those who have assisted in various ways during the compilation and publishing of this work, and the manufacturers and engineers who have so kindly furnished descriptions and photographs.

GLENN D. ANGLE.

November 10, 1921.

Airplane Engine Encyclopedia

ABADAL

The Abadal engine was produced experimentally in France during the war. It has twelve cylinders disposed in the unconventional form of a Y, the upper eight cylinders arranged in the usual 90 degree Vee form while the other four cylinders extend vertically downward.

The bore and stroke are 120 mm. (4.72 in.) and 140 mm. (5.51 in.) respectively, giving as displacement per cylinder 96.41 cu. in., and total displacement 1156.92 cu. in. The compression ratio is 4.8 to 1. The rated horsepower (350) at 2500 r.p.m. represents a performance as good as would be expected, although claims for 400 h.p. have been made. The propeller speed is reduced to .55 crankshaft speed by gearing for the sake of efficiency.

Externally the appearance of the cylinders is like those used on the well known Hispano-Suiza engines. Aluminum block construction is employed with aluminum flanges provided for bolting to the crankcase. Cast-steel cylinder heads are cast in place and steel liners or sleeves are screwed in. There are two inlet and two exhaust valves per cylinder operated from an overhead enclosed camshaft.

The crankshaft is the usual four-throw type mounted on five ball bearings, two ball bearings being also used in mounting the propeller shaft. The connecting rods have "H" sections and are of the forked type. The inner rod cap, which is babbitted on the steel on both sides, is not bolted, but held together by the two forked rods which lie side by side. The pistons are made of aluminum.

The engine is water-cooled, circulation being maintained by a centrifugal pump with three outlets, one to each block of cylinders. Carburetion is divided into threes by the use of a duplex and single unit. Lubrication is forced to the crank-pin bearings and splash is depended upon for oiling the pistons and all ball bearings. Dual ignition is provided by four magnetos. The dry weight of the engine complete is stated to be 705 lbs., hence the weight per h.p. is slightly over 2 lbs. at the rated normal output.

Fig. 1. The Abadal Twelve-Cylinder Y Type Engine.

A. B. C.

The A. B. C. engines are built by the A. B. C. Motors Ltd., formerly the All British Engine Company Ltd. of London, England. Mr. Charteris organized this firm early in 1912 with Mr. Bradshaw as chief engineer. One of the early types was a four-cylinder vertical water-cooled engine rated at 40 h.p. This engine was used by Mr. Hawker in a Sopwith biplane which won the Michelin Cup in 1912 by beating the British Duration Record.

There are also a number of water-cooled Vee types having four, six, eight, twelve, and sixteen cylinders which are reported to have been built. The smaller series with four, six, and eight cylinders had a bore of 3.75 in., a stroke of 3.125 in., and a displacement of 34.51 cu. in. per cylinder.

The four-cylinder engine was rated 30 h.p. at 1450 r.p.m. The total displacement was 138.06 cu. in., and the brake mean effective pressure at rated output was 113.6 lbs. per sq. in. The dry weight was stated to be 110 lbs., or 3.67 lbs. per h.p.

The six-cylinder Vee type engine, which had a total displacement of 207.06 cu. in., was rated 45 h.p. at 1450 r.p.m. The dry weight was stated to be 175 lbs., or 3.9 lbs. per h.p.

The eight-cylinder engine with a total displacement of 276.12 cu. in. was rated 60 h.p. at 1450 r.p.m. The dry weight was stated to be 175 lbs., or 2.92 lbs. per h.p.

Another series of A. B. C. water-cooled Vee type engines had a bore of 5 in., a stroke of 4.5 in., and a displacement of 88.36 cu. in. per cylinder.

The six-cylinder Vee type with a total displacement of 499.8 cu. in. was rated 85 h.p. at 1400 r.p.m. The brake mean effective pressure was approximately 96 lbs. per sq. in. The dry weight was stated to be 220 lbs., or 2.59 lbs. per rated h.p.

The eight-cylinder 90 degree Vee type had a total displacement of 706.88 cu. in. and was rated 100 h.p. at 1300 r.p.m. The brake mean effective pressure was approximately 86 lbs. per sq. in. The valves were located in the cylinder head and mechanically operated. The dry weight was said to be 375 lbs., or 3.75 lbs. per rated h.p.

The twelve-cylinder Vee type with a displacement of approximately 1000 cu. in. was rated 170 h.p. at 1400 r.p.m. The dry weight was stated to be 390 lbs., or 2.3 lbs. per rated h.p.

A sixteen-cylinder Vee type was designed but never built. This engine had a total displacement of 1332.8 cu. in. and was rated 225 h.p. at 1400 r.p.m. The dry weight was estimated to be 490 lbs., or 2.18 lbs. per rated h.p.

During 1913 the firm began to develop air-cooled types. The smaller of these, known as the "Gnat," is a two-cylinder horizontally opposed type while the others are radial air-

cooled designs, following quite closely the same general form of construction.

"Dragonfly." The "Dragonfly," which is the largest of the A. B. C. air-cooled radial designs, has nine cylinders with a bore and stroke of 5.5 in. and 6.5 in., respectively. The total displacement is 1389.3 cu. in., and the compression ratio 4.42 to 1. The engine is rated 320 h.p. at 1650 r.p.m. and estimated to develop 340 h.p. at 1750 r.p.m. During test it is seldom possible to develop on an average more than 295 h.p. normally at 1650 r.p.m., or 315 h.p. at 1800 r.p.m. The actual brake mean effective pressure at normal speed is approximately 103 lbs. per sq. in.

The fuel consumption has been stated to be .56 lbs. per b. h. p-hr., while tests have shown that this value may run as high as .80 lbs. per b.h.p-hr. The oil consumption is stated to be .039 lbs. per b.h.p-hr. Two Claudel-Hobson H-C-8 carburetors are mounted at the anti-propeller end and feed at four points into a baffled ring manifold from which pipes are connected to each cylinder. Lubrication is by means of a Roto-plunge pump on the Mark I engine and on the Mark II by an Albion-Murray plunger type pump, having four leads to the engine.

The cylinders are machined from steel forgings with head and cooling fins integral. The cooling fins are coated with copper for the purpose of distributing the heat and to assist in dissipating it to the cooling air. The exhaust and inlet valve ports are bolted to the cylinder head. There are three valves per cylinder, one inlet with a clear diameter of 2.66 in. and a lift of .654 in., and two exhaust valves located forward which have a clear diameter of 1.7 in. and a lift of .413 in. The inlet valve opens at top center and closes 52 degrees late, and the exhaust valve opens 64 degrees early and closes 10 degrees late. The firing order (1-3-5-7-9-2-4-6-8) is common to nine-cylinder radial engines.

The single throw crankshaft is built up in two sections with counterbalances integrally attached to each. The connecting rods are of the articulated type, the master rod having a solid crankpin end mounted upon roller bearings. The pistons are made of aluminum alloy and have three rings lo-

Fig. 2. Propeller End of A. B. C. "Dragonfly" Engine.

Fig. 3. Magneto End of A. B. C. "Dragonfly" Engine.

cated above the wrist pin. Dual ignition is provided by two nine-cylinder magnetos.

Early reports have given the dry weight as 610 lbs., but actually the engine weighs approximately 656 lbs. The overall dimensions are as follows: height 47.52 in., width 48.5 in., and the length 42.12 in.

"Gnat." The A. B. C. "Gnat" is a two-cylinder horizontally opposed air-cooled type having a bore of 110 mm. (4.33 in.) and a stroke of 120 mm. (4.72 in.). The total displacement is 139 cu. in., and the engine is rated 45 h.p. at 1800 r.p.m.

Fig. 4. A. B. C. "Gnat" Engine.

The fuel consumption is stated to be .56 pts. per h.p-hr., and the oil consumption .037 pts. per h.p-hr. The cylinders have the same form of construction as the air-cooled radial designs. The dry weight is said to be 115 lbs., or 2.56 lbs. per rated h.p.

"Mosquito." The A. B. C. "Mosquito" is a six-cylinder two-row radial air-cooled engine of 110 mm. (4.33 in.) bore and 140 mm. (5.51 in.) stroke. The total displacement is 486.84 cu. in., and the rated horsepower has been given as both 110 and 135. The fuel consumption is stated to be .505 lbs. per h.p-hr., and the oil consumption .0204 lbs. per b.h.p-hr. The carburetor is of a special A. B. C. design.

The cylinders with integral cooling fins are machined from solid steel bars and later deposited with copper similarly to the "Dragonfly" engine cylinders. There are one inlet and two exhaust valves per cylinder. The two-throw crankshaft

is mounted upon roller bearings, and the pistons are made from aluminum alloy. The dry weight is stated to be 180 lbs., and the overall diameter measures 40 in.

Apparently no great amount of development work has been carried on with the "Mosquito" engine. The seven-cylinder "Wasp" design no doubt proved to be the more promising type.

"Wasp." The A. B. C. "Wasp" (Mark I) is a seven-cylinder air-cooled radial engine of 114.3 mm. (4.5 in.) bore. 150 mm. (5.9 in.) stroke, and a total displacement of 936.78

Fig. 5. A. B. C. "Wasp" Engine.

cu. in. The engine is rated 170 h.p. at 1750 r.p.m., but tests show that it develops this power around 1800 r.p.m. The performance is undoubtedly the best of any of the A. B. C. air-cooled types as the brake mean effective pressure at 1800 r.p.m. is approximately 111 lbs. per sq. in.

The fuel consumption is .592 lbs. per h.p-hr., and the oil consumption 3.42 lbs. per hr. The mixture is supplied by two carburetors. In general the design corresponds to the nine-cylinder "Dragonfly" engine. The dry weight is approximately 290 lbs.

The "Wasp" (Mark II) seven-cylinder radial engine has a 4.75 in. bore and 6.25 in. stroke. It is rated 200 h.p. at 1800 r.p.m., and said to weigh 320 lbs., or 1.6 lbs. per rated h.p. The Mark II is a later and improved design.

ACE

The Ace airplane engine is installed in planes built by the Horace Kean Aeroplane Company of North Beach, Long Island. This is a four-cylinder vertical water-cooled engine of conventional design, having cylinders cast in one block and valves located overhead.

Fig. 6. The Ace Airplane Engine.

ADAMS-FARWELL

The first successful rotary engine was built by the Adams Company of Dubuque, Iowa. This type of engine was originated by Mr. F. O. Farwell in 1896 after trying some experiments which proved the inadvisability of making a gas turbine. A modified form of the first engine, which had three cylinders, was made to run in 1897 and placed in an express wagon for testing purposes. Another three-cylinder design, built during 1899, was probably the first rotary engine to be installed in a rubber-tired automobile, and the Adams-Farwell automobiles equipped with a later and more refined form of this engine

were placed on the market in 1903. Five-cylinder engines were also built and installed in some of the Adams-Farwell cars marketed in 1905.

The first rotary aircraft engines, designed in 1907, were arranged to drive a vertical shaft on a helicopter made by Emile Berliner. One of these engines is now in the Smithsonian Institution at Washington. The same design was later equipped with a bevel gear drive for a horizontal propeller shaft. The first flight ever made with a rotary engine was accomplished by Hamilton at Seattle in 1909, using an Adams-Farwell engine similar to the above design.

Not long after this the Gnome engine appeared in France and soon became widely known as a result of the many records established. The Gnome engines, which embodied most of the principle features brought out in the Adams-Farwell designs, have been quite closely copied by several other constructors.

In 1910 the Adams Company brought out a larger design in order to meet the demands of aviation for more powerful engines. This engine had its cylinders in the vertical plane and employed a new type of induction system.

Up to this time all Adams-Farwell engines had been designed with fixed crankshaft and revolving cylinders. The belief that the ever-increasing demand for power would soon reach a point where the gyroscopic action would interfere with airplane control led to attempts in counterbalancing the single throw crank and revolving the crankshaft and cylinders in opposite directions. It is reported that these experiments were unsuccessful owing to excessive vibration.

An engine fitted with two propellers turning in opposite directions is the latest Adams-Farwell development. This is known as the double-rotary type, and although not yet thoroughly tested, is estimated to show a very efficient performance.

36-h.p. The first Adams-Farwell rotary air-cooled airplane engine had five cylinders and was rated 36 h.p. at 1000 r.p.m., being capable of running up to a miximum speed of 1500 r.p.m. The bore was 4.25 in., the stroke 3.25 in., and the total displacement 248.25 cu. in.

No cooling device of any sort was included as a part of this engine. The steel cylinders had no external cooling ribs,

but cooled nevertheless quite evenly, due to the rapid circulation of air upon their outer surfaces when in motion.

The adjacent mounting flanges were bolted together in such a way that the cylinders revolved as if one piece. No springs were used on either inlet or exhaust valve, the valves being held to their seat during running by the centrifugal force which they exerted. All valves were operated by one cam, and a single push and pull rod and rocker arm served for both valves of one cylinder. The inlet valve was opened by the centrifugal force of the rod while the rocker acted upon the exhaust valve stem as its fulcrum, thereby insuring gas tightness for the closed valve.

An inlet pipe was located directly behind each cylinder to conduct the gas from the mixing chamber. Due to centrifugal action, the mixture was forced into the cylinders under pressure. The speed of the engine was controlled by a variable cam which regulated the closing of the inlet valve so as to retain only the required charge in the cylinder. The ignition consisted of a single-pole timer, a three-pole coil with a single vibrator, and a storage battery.

The dry weight was stated to be 97.25 lbs., or 2.7 lbs. per rated h.p. The overall diameter was 27 in. and the height when the cylinders were in a horizontal position, 16 in.

63-h.p. This engine also had five rotating cylinders. It was rated 63 h.p. at 800 r.p.m. and capable of running up to a maximum speed of 1200 r.p.m. The bore was 5.625 in., the stroke 5 in., and the total displacement 621.25 cu. in. The cylinders were made from cast iron with integral longitudinal cooling fins, but in all other respects the design was quite similar to the 36-h.p. engine.

The dry weight was stated to be 250 lbs., or 3.96 lbs. per rated h.p. The overall diameter was 34 in., and when the cylinders were in a horizontal plane the height was 20 in.

55-h.p. The 55-h.p. Adams-Farwell engine was an enlarged design of the first model. The bore was 5.25 in., and the stroke 5 in., and the total displacement 541.2 cu. in. The weight per rated horsepower is said to have been 3 lbs., the overall diameter 34 in., and the height 20 in.

72-h.p. The first Adams-Farwell five-cylinder rotary engine with cylinders in a vertical plane had a bore and stroke

of 6 in., and a total displacement of 843.23 cu. in. Originally this engine was rated 72 h.p., according to A. L. A. M. ratings, and ran normally at speeds from 950 to 1000 r.p.m. The output after making a number of refinements was actually increased to 135 h.p.

One of the principal features distinguishing this engine from some of the earlier models was the induction system. No carburetors were used, the fuel being injected into each cylinder and the power controlled by governing the amount of fuel injected. One valve, located in the cylinder head, functioned as an inlet by the admission of air, and operated as an exhaust in conjunction with auxiliary ports in the lower part of the cylinder, which were uncovered by the piston near the bottom of the stroke.

Fig. 7. Adams-Farwell Five-Cylinder Rotary Engine.

Lubrication was forced by a pump consisting of a rotary member with plungers in longitudinal chambers which were operated from end to end by stationary cams. The cylinders were made from iron with integrally cast longitudinal cooling fins. The pistons were made from cast iron and fitted with four rings. Dual ignition was employed.

The dry weight was stated to be 285 lbs., which would show 3.96 lbs. per h.p. at the original rated output, or 2.1 lbs. per h.p. for the actual output obtained after the engine had been more thoroughly developed.

Double-Rotary. The only Adams-Farwell double-rotary engine that has been built and run to date had six cylinders, a bore and stroke of 6 in., and a total displacement of 1017.9 cu. in. The output estimated at 280 h.p. and the weight stated to be 279 lbs., would represent an engine weighing less than 1 lb. per h.p., a noteworthy engineering accomplishment.

The novel feature in construction is the selection of piston and cylinder materials. The piston is of cast-steel, while the cylinder with its longitudinal cooling fins is cast from alum-

Fig. 8. Farwell Double-Rotary Engine.

inum alloy and not fitted with a liner. Although the reverse of ordinary practice it is said that cold clearance allowed between the piston and cylinder remains practically the same during running, due to the fact that the difference in the coefficent of expansion of these two metals is compensated for by their working temperature difference. Moreover, it is claimed that the unit wear would be less than in ordinary construction since there is a greater wearing surface area of the softer material exposed.

As in some of the earlier models there is one valve in the head and auxiliary exhaust ports in the lower part of the cylinder. The fuel is injected, and one cam controls the valves in all cylinders. The crankshaft revolves anti-clockwise at 1200 to 1500 r.p.m., driving a lower pitch propeller, while the cylinders revolve in a clockwise direction at 1000 to 1200 r.p.m., driving a larger pitch propeller.

A series of 5 in. bore and stroke double-rotary engines having cast aluminum alloy cylinders and cast or forged-steel pistons is proposed by Farwell to be built with six, ten, fourteen, and eighteen cylinders. The ten, fourteen, and eighteen-cylinder designs have cylinders screwed and clamped in the crankcase.

ADLER

The smaller of the German built Adler airplane engines was a water-cooled four-cylinder vertical type of 100 mm. (3.94 in.) bore, 125 mm. (4.92 in.) stroke, and 239.95 cu. in. total displacement. The rated output was 50 h.p.

The Adler six-cylinder vertical engine was rated at 100 h.p. The bore was 115 mm. (4.53 in.), the stroke 135 mm. (5.31 in.), and the total displacement 513.48 cu. in.

The cylinders were made from forged steel with head and barrel integral, and surrounded by corrugated copper water jackets. Both valves were operated by means of tappets, push rods, and rockers; and seated in removable cages that were held in place by nuts. The crankshaft was carried in seven plain bearings with individual caps bolted to the upper half crankcase. The camshaft was driven from the crankshaft by spur gears. The centrifugal water pump was mounted on the gear case cover and driven directly from the end of the camshaft.

Fig. 9. The Adler 50-h.p. Engine.

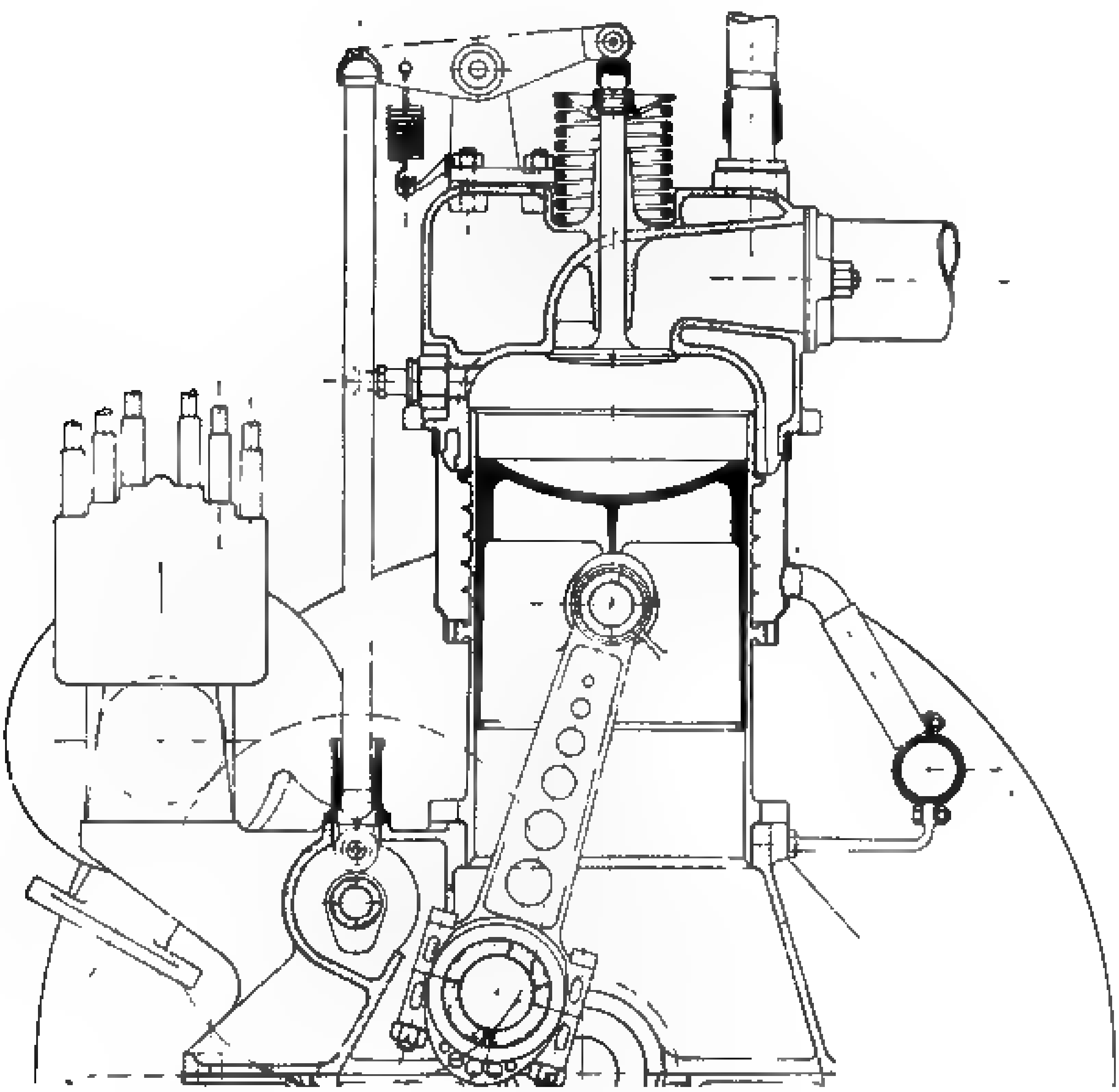


Fig. 10. Transverse Section of A. E. G. Engine.

Bosch type H. D. magnetos ran at three-fourths crankshaft speed. A special distributor, fastened to the same shaft as the oil pump, was driven from the camshaft by spiral gears. A circulating system of lubrication, such as used on the Adler automobile engines, was applied; the oil supply being carried in the base chamber.

The eight-cylinder Adler engine was in Vee form (11 degrees included) and employed two four-throw crankshafts rotating in opposite direction and connected with each other by means of gears. This engine was rated 222 h.p. at 2000-2100 r.p.m., the normal propeller speed being reduced to 1250 r.p.m. The bore was 116 mm. (4.57 in.), the stroke 160 mm. (6.3 in.), and the total displacement 826.72 cu. in. The weight was said to be 607 lbs., or 2.73 lbs. per rated h.p.

A. E. G.

The A. E. G. firm controls the N. A. G. (Nationale Automobil Gesellshaft) which first built the Wright engines under license in Germany. This concern also produced a four-cylinder vertical water-cooled engine of their own design in which the valves were situated vertically in the cylinder head and operated by push rods and rockers. The cylinder heads were cast with the water jacket integral, the cylinder barrels being screwed into the head and surrounded by sheet metal jackets held by screwed on rings.

AEROMARINE

The Aeromarine Plane and Motor Company of Keyport, N. J., have designed and constructed several vertical and Vee type airplane engines during the past seven years.

90-h.p. The first Aeromarine engine had six vertical water-cooled cylinders and was rated at 90 h.p. The actual horsepower developed at 1400 r.p.m. was said to be 85. The bore and stroke were 4.3125 in. and 5.125 in. respectively, hence the total displacement was 449.16 cu. in.

The cylinders had dome shaped heads and were cast from iron with the water jackets around the head integral. The side jackets were copper electrically deposited. Single overhead inlet and exhaust valves were operated through push rods from a camshaft in the crankcase. The crankshaft was a six-throw seven-bearing type, and an "H" section was employed

for the body of the connecting rods. The pistons were cast from iron.

The mixture was supplied by two Zenith carburetors, each feeding three cylinders. Oil pressure from 12 to 15 lbs. was maintained by a gear pump, and two Bosch D-U-6 magnetos provided the ignition. The dry weight of this engine was approximately 430 lbs.

Fig. 11. End View of Aeromarine 90-h.p. Engine.

Fig. 12. Inlet side of Aeromarine 90-h.p. Engine.

Model K-6. The Aeromarine K-6, a geared model of the 90-h.p. engine, was rated 100 h.p. at 2000 r.p.m. The propeller speed was reduced by gearing at a ratio of .571. Two Zenith carburetors furnished the mixture, and pressure lubrication was maintained by a gear pump. The fuel consumption was stated to be .63 lbs. per h.p-hr., and the oil consumption .063 lbs. per h.p-hr.

The six-throw crankshaft had seven bearings with individual caps and ball bearings mounted on each side of the driving gear. The connecting rods were of "H" section, and dual ignition was supplied by magnetos. The engine was stated to weigh 435 lbs., or 4.35 lbs. per rated h.p.

Fig. 13. Exhaust side of Aeromarine Model K-6.

Model D-12. The Aeromarine Model D-12 was rated 150 h.p. at 1400 r.p.m. This engine was a Vee type having twelve cylinders identical with those used on the above models; therefore the total displacement was 898.32 cu. in. Dual ignition was supplied by two six-cylinder Dixie magnetos, and the dry weight was stated to be 750 lbs., or 5 lbs. per rated h.p.

100-h.p. The 100-h.p. Aeromarine engine delivered its rated output at 2300 r.p.m. It had eight water-cooled cylinders arranged in Vee form, the bore being 3.5 in., the stroke 5.125 in., and the total displacement 394.48 cu. in. The propeller speed was reduced to .571 that of the crankshaft through gear-

Fig. 14. Propeller End of the Aeromarine 100-h.p. Engine.

ing that was so designed that a ratio of .5 could be substituted if desired.

One duplex Zenith carburetor supplied the mixture, and an oil pressure of approximately 30 lbs. was maintained by means of a gear pump. Dual ignition was supplied by Delco equipment, which included an electric starter and generator.

Fig. 15. Timing End of the Aeromarine 100-h.p. Engine.

The aluminum cylinders, which were cast in blocks of four, had detachable heads and hardened cast-iron liners inserted for the cylinder barrel. The crankshaft was of the three-bearing type, and the connecting rods were forked and had "H" sections. The aluminum pistons employed three rings, two located above the wrist pin and the one below serving as an oil scraper. The dry weight of the engine, including starter and generator, was stated to be 450 lbs., or 4.5 lbs. per rated h.p.

Type B—90 Degree Vee. The Aeromarine Type B engine, with eight cylinders arranged in 90 degree Vee form, develops 148 h.p. at 2275 r.p.m. and 166 h.p. at the recommended maximum speed of 2635 r.p.m. The bore is 3.625 in. and the stroke 5.125 in., hence the total displacement is 423.2 cu. in. The compression ratio is 5 to 1, and the normal brake mean effective pressure is 120 lbs. per sq. in. The propeller speed is reduced to .571, that of the crankshaft by gearing, the propeller shaft being mounted on two tapered roller bearings which are capable of taking end thrust in either direction.

Fig. 16. End View, Aeromarine Type B—90 Degree Vee Engine

The cylinders are cast in blocks of four from iron. Cylinder barrels and combustion chambers are integral and include a frame work for attaching the water jacket plates. There are two inlet and two exhaust valves per cylinder of 1.375 in. clear diameter. These are operated through single rocker arms for each pair of valves by two overhead camshafts enclosed in oil tight housings.

The crankshaft, which is of the three-bearing type, has a ball bearing mounted at the center and one just outside the drive gear. The connecting rods are forked and have "H" sections. A floating wrist pin is used in an aluminum piston which has two top rings and one lower ring acting as an oil scraper.

The gas mixture is supplied by a 1.75 in. duplex Zenith carburetor. Pressure lubrication is maintained by a three-geared duplex pump, one delivering into a high pressure line to the crankshaft bearings, another into a low pressure line to the camshaft, and a third circulating oil through the radiator and the oil reservoir.

Fig. 17. Side View, Aeromarine Type B—90 Degree Vee Engine.

A centrifugal pump with two outlets delivers about 38 gals. of water per min. As a means of assisting vaporization of the fuel, some of the water is drawn from the top of the cylinder jackets through the jacketed intake manifold to the suction side of the pump. Dual ignition is furnished by Dixie magnetos. The dry weight is stated to be 460 lbs., or 3.1 lbs. per normal h.p.

Type B—45 Degree Vee. The Aeromarine Type B, with eight cylinders arranaged in 45 degree Vee form, has cylinder dimensions corresponding with those of the Type B engine that is in 90 degree Vee arrangement. This engine is stated to develop 150 h.p. at 2275 r.p.m. and 170 h.p. at a maximum speed of 2635 r.p.m. The compression ratio is 5 to 1, and the normal brake effective pressure 121 lbs per sq. in. The propeller speed is reduced by gearing in the same manner

and at the same ratio as in the Type B-90 degree Vee engine.

The construction of these two engine differs mainly in the cylinders, which are cast in blocks of four from aluminum instead of iron, and in the connecting rods, which are of the articulated type with tubular sections instead of the forked type with "H" sections. The engine employs dual ignition and is furnished with either a Delco battery system or Dixie 800 magnetos.

The dry weight is stated to be 420 lbs., or 2.8 lbs. per normal h.p. The overall dimensions are as follows: length 42.875 in. inside propeller and 49.6875 outside propeller, height 36.875 in., and width 22.375 in.

Fig 18. End View, Aeromarine Type B—45 Degree Vee Engine.

Fig. 19. Side View, Aeromarine Type B—45 Degree Vee Engine.

Model L-6. The Aeromarine Model L-6 is a six-cylinder vertical water-cooled engine developing 130 h.p. at 1625 r.p.m., 145 h.p. at 1700 r.p.m., and 215 h.p. at a maximum permissable speed of 3000 r.p.m. The bore is 4.25 in. and the stroke 6.5 in., hence the total displacement is 553.25 cu. in. The compression

ratio is 5.25, and 122 lbs. per sq. in. b.m.e.p. is developed at 1700 r.p.m.

The L-6 engine is made in both direct drive and geared types. The direct drive engine is generally known as Model-L-6-D and the geared engine as Model L-6-G. The geared engine has a propeller reduction ratio of .535.

The fuel consumption is reported to be .5 lbs. per h.p-hr., and the oil consumption .03 lbs. per h.p-hr. Duplex Stromberg carburetors furnish the mixture, and an oil pressure of approximately 50 lbs. is maintained by a gear pump. This engine is supplied with either a dry or wet sump system.

Fig. 20. Aeromarine Type L-6.

The crankcase and cylinder water jackets are of monoblock aluminum casting. A steel cylinder sleeve whose outer surfaces are exposed to the cooling water is inserted from the top and has an annular packing ring near the lower end for the purpose of making a water tight joint. There are two inlet and two exhaust valves per cylinder, operated through rockers from an overhead enclosed camshaft. One flat multiple leaf valve spring serves for an inlet and exhaust valve which are located directly opposite. The inlet has a clear diameter of 1.75 in. and the exhaust 1.65625 in., both valves having a lift of .46875 in. and 30 degree seats.

The valve timing is as follows: inlet opens 6 degrees late and closes 42 degrees late; exhaust opens 46 degrees early and closes 10 degrees late. The firing order is 1-5-3-6-2-4.

The crankshaft is a three-bearing type with an additional bearing at the propeller end. The geared engine has a counter balanced crankshaft. The connecting rods are of tubular section and employ four bolts for holding the big end cap. The pistons are made from aluminum alloy and fitted with three compression rings and one oil scraper ring. Dual ignition may be supplied by either a battery system or magnetos.

The dry weight of the L-6-D engine is stated to be 400 lbs., or 2.76 lbs. per normal h.p. Including the cooling system, the weight is said to be 500 lbs. The geared engine with starter and generator is stated to weigh 490 lbs. The overall dimensions are as follows: length 59 in., height 36.5 in., and width 16 in.

Fig. 21. Aeromarine Type L-6-D.

Model L-8. The Aeromarine Model L-8 has corresponding cylinder dimensions and follows quite closely the design of the L-6 type. This engine has eight cylinders in 60 degree Vee arrangement, and develops normally 192 h.p. at 1750 r.p.m. The total displacement is 737.67 cu. in., and the normal brake mean effective pressure 117.6 lbs. per sq. in. At normal horsepower, the fuel consumption is .474 lbs. per b.h.p-hr., and the oil consumption .0315 per b.h p-hr.

The connecting rods have tubular sections and are of the forked type. Dual ignition is either supplied by a Delco unit with distributors mounted on the end of the camshafts or by

Fig. 22. End and Section of Aeromarine Model L-8.

two-spark magnetos. The dry weight is 556.5 lbs., or 2.9 lbs. per normal b.h.p. The overall dimensions are as follows: length over propeller hub 49 in., height 34.25 in., and width 32.6875 in.

The L-8 models are built for both direct drive propeller and with reduction gears, the same as Model L-6. The direct drive engine is known as the L-8-D and the geared engine as the L-8-G.

U Types. The Aeromarine Models U-6 and U-8 are later and improved designs of the L-6 and L-8 engines.

Fig. 23. Longitudinal Section of Aeromarine Model L-8.

AEROMOTOR

The Detroit Aeronautic Construction Co., whose address was 74 Crane Ave., Detroit, Michigan, during 1910 and 1911 produced four and six-cylinder vertical water-cooled engines, known as the Aeromotor. These engines were rated at 30 and 75 h.p. respectively, and operated at speeds from 1000 to 1500 r.p.m.

The cylinders were cast in one block of gray iron with the intake manifold integral. The hollow crankshaft was cut from a solid bar of steel. Schebler carburetors provided the mixture, and Mea magnetos the ignition.

[illegible] inder Aeromotor.

AEROPLANE

An eight-cylinder water-cooled Vee type engine, known as the Aeroplane, was produced in England as early as 1910. The cylinders had a 101 mm. (3.98 in.) bore and the stroke was 120 mm. (4.72 in.). The total displacement was 470 cu. in., and at 1500 r.p.m. the engine was rated at 59 h.p.

A displacement of 8 cu. in. per h.p. and a brake mean effective pressure of 66.2 lbs. per sq. in. does not compare favorably with present day airplane engine performance. The dry weight of the engine was stated to be 452 lbs., or 7.6 lbs. per h.p.

Fig. 25. The 50-h.p. Albatross Engine.

ALBATROSS

The Albatross engines were designed and built by Mr. Fred Weinberg of Detroit, Michigan, during the years 1910 and 1911. These engines appeared coincident to the Anzani radial types in France and are probably the first six-cylinder fixed-radial designs built in America. Mr. Weinberg has also designed and built several experimental types, including the early Gyro rotary, Detroit Aero, and others.

50-h.p. The first Albatross engine was a six-cylinder air-cooled radial type rated 50 h.p. at 1230 r.p.m. The cylinder bore was 4.5 in. and the stroke 5 in., giving a displacement of 79.5 cu. in. per cylinder and a total displacement of 477 cu. in. At this rated output the brake mean effective pressure was only 67.5 lbs. per sq. in.

The cylinders were made from semi-steel with integral horizontal cooling fins which were not machined. The one inlet and one exhaust valve per cylinder each had a clear diameter of 2.125 in. The crankshaft had two crank throws and was mounted in double-row ball bearings. The connecting rods were of the articulated type with an "H" section for the body. The pistons were made from semi-steel and had three rings located above the wrist pin.

The type of carburetor to be used was not specified, this being left optional. The engine was equipped with magneto ignition, and employed forced lubrication to the bearings. The weight stated to be 250 lbs., gives a weight of 5 lbs. per rated h.p. The overall diameter was 45 in. and the overall length 25 in.

100-h.p. The larger Albatross engine was a six-cylinder radial water-cooled type rated 100 h.p. at 1230 r.p.m. The cylinder bore was 5.5 in., the stroke 5 in., and the total dis-

Fig. 26. The 100-h.p. Albatross Engine.

placement 712.43 cu. in. The general arrangement and design of this engine was quite similar in many respects to the air-cooled type. The weight stated to be 275 lbs. shows 2.75 lbs. as the weight per rated h.p.

ALVASTON

The Alvaston engines were all horizontally opposed water-cooled types. A feature common to all Alvaston engines was the method of attaching the cylinders to the crankcase. This consisted of long bolts extending out from the crankcase to a bridge placed across the cylinder heads.

20-h.p. The smaller Alvaston engine had two cylinders with a bore and stroke of 114 mm. or 4.48 in., and a total displacement of 141.24 cu. in. It was rated 20 h.p. at 1200 r.p.m., corresponding to a brake mean effective pressure of 93.5 lbs. per sq. in. The crankshaft was fitted with a fly wheel. The dry weight of the engine, excluding the fly wheel, was stated to be 95 lbs., or 4.75 lbs. per h.p.

30-h.p. Another two-cylinder Alvaston engine had a 132 mm. (5.2 in.) cylinder bore and a 127 mm. (5 in.) stroke. With 212.37 cu. in. total displacement, the rated 30 h.p. at 1200 r.p.m. represents a brake mean effective pressure approximately the same as the smaller engine. Without flywheel the weight was stated to be 120 lbs., or 4 lbs. per h.p.

50-h.p. The four-cylinder Alvaston engine was rated 50 h.p. at 1200 r.p.m. At this rating the brake mean effective pressure would be 103.8 lbs. per sq. in., a somewhat higher value than found in the two-cylinder engines. The bore and stroke were 144 mm. (4.48 in.) and 128 mm. (5.04 in.) respectively, thus giving a total displacement of 317.8 cu. in. Auxiliary exhaust ports were located in the cylinder so as to be uncovered by the piston near the end of the expansion stroke. The dry weight was stated to be 160 lbs. without fly wheel, or 3.2 lbs. per rated h.p.

A. M. U. A. L.

"Establishments A. M. U. A. L." of France build three eight-cylinder water-cooled Vee type engines for aeronautical purposes. Each is fitted with two carburetors and the same number of oil pumps which are located at opposite ends of the engine.

M. J. 5. The model M. J. 5—A. M. U. A. L. engine has cylinders arranged in 65 degree Vee form. The bore and stroke are 150 mm. (5.91 in.) and 200 mm. (7.87 in.) respectively, and the total displacement 1729.12 cu. in. The engine is rated 350 h.p. at 1400 r.p.m., corresponding to a brake mean effective pressure of 114 lbs. per sq. in. The weight is stated to be 805 lbs., or 2.3 lbs. per rated h.p.

M. J. 6. The Model M. J. 6—A. M. U. A. L. engine has the same bore and stroke as the Model M. J. 5, but the cylinders are arranged with 90 degrees as the included angle of the Vee instead of 65. The rated output is 400 h.p. at 1450 r.p.m., corresponding to a brake mean effective pressure of 126 lbs. per sq. in.

Fig. 27. The A. M. U. A. L. Type M. J. 7 Engine.

M. J. 7. The Model M. J. 7—A. M. U. A. L. engine is an eight-cylinder 90 degree Vee type of 180 mm. (7.09 in.) bore and 210 mm. (8.27 in.) stroke. The displacement per cylinder is 326.5 cu. in. and the total displacement 2612 cu. in.

The engine is rated 600 h.p. at 1400 r.p.m. and 700 h.p. at 1600 r.p.m At these ratings the brake mean effective pressure would be 130 and 132.5 lbs. per sq. in. respectively. By the use of a special air turbine as a means of cooling the exhaust valves, it is said that the M. J. 7 type engine can be made to run at 1800 r.p.m and develop 800 h.p.

ANSALDO

The Ansaldo San Giorgio Company, which is no doubt the largest and most noted manufacturing firm in Italy, began building airplane engines during the war by first constructing the Spa 6-A type. In 1917 plans were laid for their own designs, descriptions on four of which have been published to date. In certain details these engines somewhat resemble the Spa.

Type 4-E. 150. This engine is a six-cylinder vertical water-cooled type rated 300 h.p. at 1700 r.p.m.

Fig. 28. Ansaldo, Type 4-E. 150.

Type 4-E. 145. This is a six-cylinder vertical water-cooled engine rated at 300 h.p. and said to have developed 290 h.p. at 1650 r.p.m. and 310 h.p. at 1800 r.p.m., its recommended maximum speed. The cylinders are 145 mm. (5.17 in.) bore and the stroke is 180 mm. (7.09 in.), giving 181.56 cu. in. displacement per cylinder and a total displacement of 1089.36 cu. in. The corresponding normal brake mean effective pressure is 129.5 lbs. per sq. in.

The consumption of fuel is stated to range from .473 to .484 lbs. per h.p-hr. There are two Zenith carburetors, each

feeding three cylinders. Lubrication is fed under pressure by means of gear pumps, and dual ignition is supplied by two six-cylinder magnetos.

The individual steel cylinders have welded sheet metal water jackets and are fitted with two inlet and two exhaust valves which are operated from an overhead camshaft. The connecting rods are of tubular section, and the pistons are made from aluminum. The dry weight is stated to be 639 lbs., or 2.13 lbs. per rated h.p. This engine is reported as still in the development stages.

Type 4-E. 284. This is a twelve-cylinder 60 degree Vee type water-cooled engine of 140 mm. (5.51 in.) bore and 180 mm. (7.09 in.) stroke. The displacement per cylinder is 169.06 cu. in. and the total displacement 2028.72 cu. in. This

Fig. 29. Ansaldo, Type 4-E. 284.

engine is rated at 450 h.p., but is said to actually develop normally 520 h.p. at 1650 r.p.m, and as maximum 570 h.p. at 1800 r.p.m. The corresponding normal brake mean effective pressure is 123 lbs. per sq. in.

The individual cylinders are of steel with welded on water jackets. There are two inlet and two exhaust valves per cylinder operated from two overhead camshafts. Articulated type connecting rods are used.

The consumption of fuel is stated to range from .473 to .484 lbs. per h.p-hr., and the consumption of oil from .022 to .033 lbs. per h.p-hr. The two Zenith carburetors, which are

located in the Vee, each supply six cylinders. Pressure lubrication is maintained by a gear pump and the oil reservoir is located in the base chamber. Ignition is by two magnetos, each supplying six cylinders. The dry weight is stated to be 1125 lbs., or 2.5 lbs. per rated h.p.

Type 4-E. 29. This is a twelve-cylinder Vee type water-cooled engine rated 550 h.p. at 1650 r.p.m.

Fig. 30. Ansaldo, Type 4-E. 29.

ANTOINETTE

The Antionette engines, which Levavasseur constructed in France as early as 1907, were perhaps the most remarkable multi-cylinder Vee type engines of their time. Eight, sixteen, and thirty two-cylinder water-cooled Vee type models were constructed. One of the most interesting features was the employment of fuel injection instead of carburetors. Individual plunger pumps operated by variable throw eccentrics were used to inject the fuel directly into the valve port.

The cooling system was of unusual design, the water being boiled in the jackets, condensed in a large aluminum

condenser and then returned to the engine by means of a small belt driven pump. The cylinders had drop-forged steel heads and jackets of copper electrically deposited. The valves were located at the side of the combustion chamber one above the other, the inlet being of the automatic type.

Fig. 31. Sixteen-Cylinder 134-h.p. Antoinette Engine.

Fig. 32. Eight Cylinder 55-h.p. Antoinette Engine.

32-h.p. This engine had eight water-cooled cylinders in Vee arrangement and was rated 32 h.p. at 1400 r.p.m. The bore and stroke were 80 mm. (3.15 in.), hence the total displacement of the engine was 196.4 cu. in. The brake mean effective pressure at rated horsepower was 92.5 lbs. per sq. in. The dry weight was stated to be 93 lbs., or 2.9 lbs. per rated h.p.

67-h.p. This was an eight-cylinder Vee type engine rated 67 h.p. at 1100 r.p.m. The bore was 110 mm. (4.33 in.), the stroke 105 mm. (4.13 in.), and the total displacement 486.56 cu. in. The brake mean effective pressure at normal rating was approximately 99 lbs. per sq. in. The dry weight was stated to be 209 lbs., or 3.1 lbs. per rated h.p.

64-h.p. The 64-h.p. Antoinette had sixteen cylinders of the same dimensions as the 32-h.p. engine. The dry weight was stated to be 165 lbs., or 2.6 lbs. per rated h.p.

134-h.p. This was a sixteen-cylinder Vee type engine having the same dimensions as the 67-h.p. model. The dry weight was stated to be 264 lbs., or approximately 2 lbs. per rated h.p.

55-h.p. The 55-h.p. Antoinette engine was an eight-cylinder Vee type developed later than the eight and sixteen-cylinder models described above.

ANZANI

Anzani airplane engines have been more or less prominent ever since 1908, when the first designs made their appearance in France. The Anzani firm had become well known as builders of motorcycle engines, and the influence of this experience was clearly exhibited in their earlier models by the fan-shaped arrangement of cylinders. Fears of the troubles associated with excessive lubrication in cylinders below the horizontal doubtless led to the early adoption of this rather peculiar cylinder arrangement, but additional experience proved that with carefully designed forced lubricating systems the oiling difficulties were not of such a serious nature. The fan-type airplane engine, for several obvious reasons, has long since been abandoned in favor of the radial form having cylinders symmetrically disposed about the crankshaft center.

Probably the best known Anzani engines are the air-cooled radial types. It is interesting to note that among the various other forms which have been built none are of the more conventional types such as the vertical. Practically all of the designs were fitted with Zenith carburetors and Gibaud magnetos. Anzani engines have been produced in England and Italy, and also used to some extent in other countries.

Vee types. During the years 1910 and 1912 Anzani produced two sizes of four-cylinder water-cooled Vee type engines, which had cast-iron cylinders with integral water jackets.

Fig. 33. The Anzani "W" Type Engine.

The smaller of these engines, which was rated from 30 to 32 h.p. at 1600 r.p.m., had a bore of 100 mm. (3.94 in.), a stroke of 120 mm. (4.72 in.), and a total displacement of 230.2 cu. in. The weight was stated to be 187 lbs. The overall dimensions were as follows: length 26 in., height 26 in., and width 19 in.

The larger four-cylinder water-cooled Vee type engine was rated 56 h.p. at 1400 r.p.m. The bore was 135 mm. (5.31 in.), the stroke 150 mm. (5.91 in.), and the total displacement 523.52 cu. in. The weight of this engine was stated to be 308 lbs., or 5.4 lbs. per rated h.p.

"W" Types. The six-cylinder water-cooled "W" type Anzani engine was quite similar in construction to the air-

cooled fan types. The cylinders were made from cast iron with integral water jackets. The crankshaft had two throws, and the connecting rods were of the forked type.

Fan Types. The Anzani two-cylinder fan or Vee type engine had cast-iron cylinders upon which were attached perforated sheet metal cooling flanges. A series of holes, serving as auxiliary exhaust ports, were located in the cylinder barrel so as to be uncovered by the piston near the end of the stroke.

Fig. 34. Anzani Two-Cylinder Vee Type.

Rated h.p.	14	15	24.5	31.6	42.3
Bore (mm.)	85	85	105	120	135
Bore (in.)	3.35	3.35	4.13	4.72	5.31
Stroke (mm.)	85	100	130	130	150
Stroke (in.)	3.35	3.94	5.12	5.12	5.91
Normal r.p.m.	1800	1800	1600	1500	1400
Displacement (cu. in.)	88.59	104.19	205.77	268.77	392.64
Weight in lbs.	77	94	145	176	231
Wt. per rated h.p.	5.50	6.27	5.91	5.57	5.46

Anzani Three-Cylinder Fan Type Engines.

There are on record, five models of Anzani three-cylinder air-cooled fan type engines, the principle characteristics of which are given in the table. Perhaps the most interesting of these is the 24.5-h.p. engine, as it was used by Bleriot in his monoplane which crossed the English channel for the first time in July, 1909.

The cylinders were made from cast iron with cooling fins integral. The valves were situated in a pocket at the back of the combustion chamber, one above the other. The inlet, the upper of the two valves, was operated automatically.

Fig. 35. Anzani Three-Cylinder Fan Type.

The built-up crankshaft had a single crank pin, and in place of the ordinary crank checks were disks serving both as flywheels and balance weights. The shaft was mounted on two plain bearings. The connecting rods of the two outer cylinders were forked so as to straddle the plain rod of the center cylinder. The angle between the center and either outside cylinder was 72 degrees. Obviously this did not permit equal intervals between impulses or firing.

The piston was cast from iron and fitted with two piston rings above the wrist pin. Ignition was provided by Bosch magnetos. The overall dimensions of this engine reported as follows: length 26 in., height 25 in., and width 36 in.

Three-Cylinder Radials. An improved arrangement of cylinders, as compared with the fan-type engine, is found in three-cylinder radial design. The angular distance between cylinders is 120 degrees and the fire impulses occur evenly every 240 degrees of crank rotation. Three-cylinder air-cooled Anzani radial engines were used to some extent in school machines.

The bore and stroke were 105 mm. (4.13 in.) and 120 mm. (4.72 in.), respectively. The total displacement was 189.69 cu. in. and with a rating of 30 h.p. at 1300 r.p.m. it is figured that the brake mean effective pressure was nearly 96 lbs. per

Fig. 36. Anzani Three-Cylinder Radial Engine.

sq. in. The consumption of fuel ranged from .60 to .64 lbs. per b.h.p-hr., and the consumption of oil was approximately .11 lbs. per b.h.p-hr. The engine was stated to weigh 121 lbs., or 4.03 lbs. per rated h.p. Except for the location of the valves and the method of attaching the cylinders, the design was in many respects similar to the fan-type engine.

Five-Cylinder Radials. The five-cylinder air-cooled radial engines which Anzani constructed, were at one time

used quite extensively in French school machines. These engines developed from 40 to 50 h.p., and were stated to weigh 159 lbs. The cylinders were of the same type of construction as those on most of the Anzani air-cooled engines.

An interesting feature of this engine was the induction system. From a mixing chamber in the crankcase, which was fed by one carburetor, there extended tangentially an inlet pipe to each of the five cylinders. By such an arrangement, there might be expected a somewhat higher degree of volumetric filling, due to a more direct flow of the gas from the mixing chamber. The gas has a tendency to whirl, and likewise exert a force outward as it is drawn from the mixing chamber by each of the cylinders in their order of firing.

Fig. 37. Anzani 40-h.p. Six-Cylinder Engine.

Six-Cylinder Radials. The Anzani six-cylinder air-cooled radial designs have been built in two sizes. In these engines the cylinders are arranged in two rows of three each, and are in reality double forms of three-cylinder radial units.

The cylinders with cooling ribs are cast from iron and held to the crankcase by long bolts from bosses at the top. The overhead valves stand vertically and seat directly on the flat cylinder head. The inlet is operated automatically, and the exhaust by means of a push rod and rocker arm.

The two-throw crankshaft has two bearings, and is counterbalanced. Combination ball and plain bearings are used, there being an extra ball bearing at the propeller end for taking both radial load and thrust.

The connecting rods have an "H" section, and are of the slipper type. The crank pin end of each rod has a shoe in the form of a portion of a hollow cylinder with helical edges, which is held upon the split bronze sleeve by a pair of bronze collars clamped together. The cast-iron pistons are fitted with two top rings.

The smaller six-cylinder radial engines had a bore and stroke of 90 mm. (3.54 in.) and 120 mm. (4.72 in.) respectively, and a total displacement of 278.75 cu. in. The engine was rated at 40 to 45 h.p. and operated normally at 1300 r.p.m. Reports on fuel consumption range from .51 to .60 lbs. per h.p-hr., and the oil consumption was approximately .11 lbs. per h.p-hr. The weight was stated to be 154 lbs.

The larger Anzani six-cylinder radial engine had a bore and stroke of 105 mm. (4.13 in.) and 120 mm. (4.72 in.), respectively, and a total displacement of 379.38 cu. in. This engine was rated at 50 to 60 h.p. and operated normally at 1300 r.p.m. Reports on fuel consumption range from .52 to .60 lbs. per h.p-hr., and the oil consumption was approximately .11 lbs. per h.p-hr. The dry weights of this egine have been stated to be both 176 and 200 lbs.

Ten-Cylinder Radials. The Anzani ten-cylinder air-cooled radial engines follow the same general form of construction as the smaller models just described. These engines consist of two rows of five cylinders each, and employ a two-throw crankshaft. Specifications of the various models which

have been built are arranged according to total piston displacement and not necessarily in the order of their appearance.

464.6 cu. in. This engine had a bore of 90 mm (3.54 in.) and a stroke of 120 mm. (4.72 in.). At a normal speed of 1250 r.p.m. various references have given the rated horsepower as 60, 65, and 70. One of these reports a fuel consumption of .59 lbs. per h.p-hr., and an oil consumption of .11 lbs. per h.p-hr. Dry weights of 216 and 242 lbs. have also been given.

503.9 cu. in. The bore and stroke of this engine were 90 mm. (3.54 in.) and 130 mm. (5.12 in.) respectively. The rated output was 80 h.p. at 1250 r.p.m. The fuel consumption was

Fig. 38. Anzani Ten-Cylinder 100 110-h.p. Engine.

approximately .60 lbs. per h.p-hr., and the oil consumption .11 lbs. per h.p-hr. The dry weight was stated to be 225 lbs., or 2.81 lbs. per rated h.p.

738.1 cu. in. This engine, with a bore of 105 mm. (4.13 in.) and a stroke of 140 mm. (5.51 in.), gave 100 h.p. at 1100 r.p.m. and 110 h.p. at 1200 r.p.m. The consumption of fuel and oil was approximately the same as the 80-h.p. (503.9 cu. in.) engine. The dry weight was approximately 300 lbs.

764.9 cu. in. An engine rated from 95 to 100 h.p. at 1250

r.p.m. had the same cylinder bore with the stroke increased to 145 mm. (5.71 in.). The fuel consumption was reported as .627 lbs. per h.p-hr., and the oil consumption .128 lbs. per h.p-hr. Dry weights of 363 and 384 lbs. have been given. This engine has also been built with steel cylinders which had integral cooling fins.

952.5 cu. in. This engine had a bore of 115 mm. (4.53 in.) and a stroke of 150 mm. (5.91 in.), and was rated 125 h.p. at 1200 r.p.m. The fuel consumption was stated to be .57 lbs. per h.p-hr., and the oil consumption 2.3 gals. per hr. The dry weight was said to be 460 lbs., or 3.68 lbs. per rated h.p.

1043.14 cu. in. The same cylinder bore with a stroke increased to 155 mm. (6.1 in.) was used on another ten-cylinder design which was rated 125 h.p. at 1250 r.p.m. The fuel consumption of this engine was stated to be .59 lbs. per h.p-hr., the oil consumption .11 lbs. per h.p-hr., and the dry weight 465 lbs., or 3.72 lbs. per rated h.p.

There have been reports of an experimental ten-cylinder Anzani engine which was rated at 200 h.p.

Fourteen-Cylinder Radial. The Anzani fourteen-cylinder air-cooled radial engine was rated 150 h.p. at 1100 r.p.m. The bore and stroke were 105 mm. (4.13 in.) and 140 mm. (5.51 in.) respectively, and the total displacement 1033.34 cu. in. The design was similar to the ten-cylinder air-cooled radial engine of corresponding cylinder dimensions.

Twenty-Cylinder Radial. The Anzani twenty-cylinder air-cooled engine had a 105 mm. (4.13 in.) bore and a 140 mm. (5.51 in.) stroke, the same as the fourteen and one of the ten-cylinder designs. The total displacement of this engine was 1746.2 cu. in., and it was rated 200 h.p. at 1250 r.p.m. The consumption of fuel, according to various references, ranges from .50 to .59 lbs. per h.p-hr., and the oil consumption .11 lbs. per h.p-hr. The dry weight was approximately 680 lbs., or 3.4 lbs. per rated h.p.

The four rows of cylinders were arranged sufficiently close together by staggering to place two five-cylinder connecting rod assemblies side by side on one crank pin. The two-throw crankshaft was made with an included angle of 162 degrees between crank pins in order to allow even periods of firing.

Fig. 39. Anzani Twenty-Cylinder Air-cooled Engine.

Fig. 40. Anzani Twenty-Cylinder Water-cooled Engine.

The induction system consists of two mixing chambers, one at the front and the other at the rear, each fed from one carburetor. A double system of lubrication is employed, and two magnetos furnish the ignition. The exhaust valves of the first two rows of cylinders are operated from the front and those of the second two rows from the rear. The inlet valves operate automatically.

Water-cooled Radial. The latest Anzani development is a twenty-cylinder water-cooled radial engine of 140 mm. (5.51 in.) bore, 150 mm. (5.91 in.) stroke, and 2818.45 cu. in. total displacement. This engine is rated at 600 h.p., and said to develop 650 h.p. at 1700 r.p.m. and 700 h.p. at maximum speed. The weight is stated to be 1212 lbs., or 2.02 lbs. per rated h.p., and the overall diameter 51 in.

The cylinders are cast of aluminum in pairs with a common water jacket, hence the general arrangement is two rows of ten, one directly behind the other. The inlet of the rear cylinder is located at the rear, and that of the front cylinder in front, along with the overhead camshaft drive. An exhaust port common to both cylinders is located at one side of the block.

ARGUS

The Argus, which is said to be the first German airplane engine, was built by the Argus Motoren G.m.b.H. of Berlin, a firm established in 1900 for the purpose of manufacturing automobile parts. The early models closely followed motor car engine lines, at first not very reliable, but later refined to such an extent that during 1912 Argus engines were used almost exclusively in German airplanes. They were superseded, however, by the superior Mercedes and Benz designs in 1913 and 1914 and were used to a very limited extent during the war.

The Argus engines are all vertical water-cooled types with either four or six cylinders. Both steel and cast-iron cylinder construction were used. The cast cylinders were made up in pairs, while the steel cylinders were turned from solid billets and had valve cagings and water jackets welded in place. The valves were located in the cylinder head and operated by means of push rods and rockers from a camshaft

in the crankcase. The pistons were made from grey iron and provided with three rings. The connecting rods had "H" sections, and the ignition was supplied by Bosch magnetos.

Type I. This was a four-cylinder engine of 124 mm. (4.88 in.) bore and 130 mm. (5.12 in.) stroke, having a total displacement of 383.04 cu. in. The first Argus engines of this size were rated 50 h.p. at 1250 r.p.m., and weighed 264 lbs., or 5.3 lbs. per rated h.p.

Later this engine was rated 70 h.p. at 1250 r.p.m., and stated to weigh 287 lbs., or 4.1 lbs. per rated h.p. The brake mean effective pressure would be 115.7 lbs. per sq. in., according to this rating, and the fuel consumption was reported to be .584 lbs. per h.p-hr.

Fig. 41. Inlet Side of Argus 70-h.p. Engine.

Type II. This was a four-cylinder engine of 140 mm. (5.51 in.) bore and stroke, and a total displacement of 525.52 cu. in. It was rated 100 h.p. at 1250 r.p.m., corresponding to 117.7 lbs. per sq. in. b.m.e.p. Splash lubrication was employed, and the fuel consumption was stated to be .527 lbs. per h.p-hr. Weight values of both 309 and 348 lbs. have been given.

Type III. This was a six-cylinder engine with cylinder dimensions corresponding to Type I, hence the total displacement was 574.56 cu. in. Rated 110 h.p. at 1300 r.p.m., the

Fig. 42. Exhaust Side of Argus 100-h.p. Engine.

brake mean effective pressure would be 116.5 lbs. per sq. in. The fuel consumption was stated to be .578 lbs. per h.p-hr., and the dry weight 430 lbs., or 3.9 lbs. per rated h.p.

Type IV. This was a four-cylinder engine of 155 mm. (6.1 in.) bore, 165 mm. (6.5 in.) stroke, and a total displacement of 739.84 cu. in. It was rated 140 h.p. at 1250 r.

Fig. 43. Inlet Side of Argus 140-h.p. Engine.

p.m. and 150 h.p. at 1300 r.p.m. At 1250 r.p.m. the brake mean effective pressure would be 116 lbs. per sq. in. The dry weight was stated to be 420 lbs., or 2.8 lbs. per rated h.p. at 1300 r.p.m.

Type V. This was a six-cylinder engine having a displacement of 788.34 cu. in., since the cylinder dimensions were the same as Type II. The engine was rated 140 h.p. at 1250 r.p.m., which corresponds to 112 lbs. per sq. in. b.m.e.p. The dry weight was stated to be 529 lbs., or 3.77 lbs. per rated h.p.

Fig. 44
Argus
115 130-h.p.
Engine.

Type VI. This was a six-cylinder engine with cylinder dimensions corresponding to Type IV. Having a total displacement of 1139.76 cu. in. and rated 210 h.p at 1250 r.p.m., the brake mean effective pressure was 116.5 lbs. per sq. in. The dry weight was stated to be 683 lbs., or 3.25 lbs. per rated h.p.

Type VII. This was a six-cylinder engine of 130 mm. (5.12 in.) bore and stroke, and 632.04 cu. in. total displacement. This engine has been rated at both 115 and 130 h.p. at 1350 r.p.m. The brake mean effective pressure at this speed if 115 h.p. is developed would be 107 lbs. per sq. in. and 120 lbs. per sq. in. if 130 h.p. is developed.

The mixture was supplied by a Duplex Claudel carburetor. A force feed system of lubrication was used, and dual

Fig. 45. Inlet Side of Argus 190-h.p. Engine.

ignition furnished by two six-spark high-tension Bosch magnetos. The crankshaft was carried in four plain bearings. Light weight cast-iron pistons were ribbed on the interior and fitted with three rings.

Type VIII. This was a six-cylinder engine of 150 mm. (5.91 in.) bore, 145 mm. (5.7 in.) stroke, having a total displacement of 939.84 cu. in. It was rated normally 190 h.p. at 1350 r.p.m., representing 118 lbs. per sq. in. b.m.e.p. This engine follows closely the design of the Argus Type VII.

Fig. 46. Exhaust Side of Argus 190-h.p. Engine.

ARGYLL

The Argyll, which was probably the first single sleeve valve engine built for aeronautical purposes, was brought out by the well-known British motor car manufacturers, Messrs. Argylls, Ltd., and exhibited at the Olympia show in 1914.

Fig. 47. The Argyll Aircraft Engine.

This was a six-cylinder vertical water-cooled engine of 125 mm. (4.92 in.) bore and 175 mm. (6.89 in.) stroke. The displacement per cylinder was 130.99 cu. in. and the total displacement 785.94 cu. in. It was rated 120 h.p. at 1200 r.p.m., but gave 130 h.p. at this speed during preliminary tests. The brake mean effective pressure at the rated output was approximately 100 lbs. per sq. in. The dry weight including the radiator was stated to be 600 lbs.

The individual cylinders were of steel construction, having sheet-steel water jackets welded in place, and provided with ribs around the lower portion of the cylinder for cooling. The mixture was supplied by two Zenith carburetors. The fuel consumption was stated to be .47 lbs. per h.p-hr. Oil was fed to the main bearings from a pump, and the crankpins dipped into a trough. Bosch magnetos furnished the ignition.

ARMSTRONG-SIDDELEY

The Armstrong-Siddeley Motors, Ltd., of Coventry, England, build three types of air-cooled airplane engines which they placed on the market the year following the war.

The cylinder design used on all three engines consists of a steel cylinder barrel screwed into an aluminum head upon both of which are formed horizontal cooling fins. A single inlet and exhaust valve each seat on a bronze ring which is expanded into place and afterwards machined. In each case the bore and stroke are 127 mm. (5 in.), giving as displacement per cylinder 98.175 cu. in. The crankshafts are all mounted upon roller bearings.

"Ounce." The Armstrong-Siddeley "Ounce" is a two-cylinder horizontally opposed engine rated normally 45 h.p. at 1600 r.p.m. At 1800 r.p.m. the engine develops 50 h.p. The compression ratio is 5.1, and the brake mean effective pressure is 113 lbs. per sq. in. at normal speed. The fuel consumption is stated to be 25.2 lbs. per hr , and the oil consumption 3.3 lbs. per hr. Lubrication is of the dry sump type with pressure maintained by a double oil pump. Dual ignition is supplied by a Remy set and one magneto. The dry weight is stated to be 170 lbs., or 3.77 lbs. per rated h.p. The overall dimensions are as follows: length 20.5 in., height 24.5 in., and width 39.5 in.

Fig. 48. The Armstrong-Siddeley "Ounce" Engine.

"Lynx." The Armstrong-Siddeley "Lynx" engine has a radial arrangement of seven cylinders. It is rated at 150 h.p., and has a total displacement of 687.23 cu. in. The fuel consumption is stated to be 92.4 lbs. per hr., and the oil consumption 9 lbs. per hr. The dry weight is stated to be 390 lbs., or

2.6 lbs. per rated h.p. The overall diameter is 42 in. and the length 33.5 in.

Fig. 49. The Armstrong-Siddeley "Lynx" Engine.

Fig. 50. The Armstrong-Siddeley "Jaguar" Engine.

"Jaguar." The Armstrong-Siddeley "Jaguar" fourteen-cylinder engine is a double form of the seven-cylinder radial type and corresponds with it in most of its details. This engine is rated 300 h.p., and has a total displacement of 1374.45 cu. in. The fuel consumption is 184.5 lbs. per hr., and the oil consumption 21.6 lbs. per hr. Dual ignition is supplied by a Remy set. The weight is stated to be 680 lbs., or 2.27 lbs. per rated h.p. The overall diameter is 42 in. and the length 41 in.

ARMSTRONG-WHITWORTH

The Armstrong-Whitworth Company of England have built an experimental twelve-cylinder water-cooled 45 degree Vee engine of the Ricardo supercharger type.

Fig. 51. Front View, Armstrong-Whitworth Engine.

Fig. 52. Side View, Armstrong-Whitworth Engine.

ASAHINA

The Asahina engine, which bears the name of its designer, was entered in a prize contest held by the Imperial Aviation Association of Japan for airplane engines designed and constructed in that country. The tests took place June 22, 1917, at an aviation field near Tokio.

Owing to the failure of one of the parts, the Asahina engine was unable to complete more than one and one-half hours' running during the contest. At no time during the runs did the engine develop more than 77 h.p., although it was rated 100 h.p. at 1100 r.p.m. It is reported that the design was original and showed evidence of careful study, but was very poorly constructed.

This was a nine-cylinder air-cooled rotary engine of 4.5 in. bore and 5 in. stroke. With a total displacement of 715.5 cu. in., 100 h.p. could easily have been expected. The weight was stated to be 414 lbs.

Fig. 53. Twelve-Cylinder Ashmusen Engine.

ASHMUSEN

The Ashmusen Manufacturing Company of Providence, R. I., manufacture two horizontal types of air-cooled engines.

Eight-Cylinder. The smaller of these is an eight-cylinder direct-drive engine rated at 60 h.p. The cylinders have separate barrels and a cast-in-block head which is held by through bolts to the crankcase. The inlet and exhaust valves stand vertically side by side, and are operated directly from a camshaft underneath.

The crankshaft, which may have either direction of rota-

tion, is mounted upon three ball bearings. The connecting rods have "H" sections. Two carburetors are hung directly below on manifolds which are attached to the cylinder heads. Forced feed lubrication is employed, and ignition may be supplied by either battery or magneto with one spark plug per cylinder. The dry weight is stated to be 235 lbs., or 3.9 lbs. per rated h.p.

Twelve-Cylinder. The twelve-cylinder Ashmusen engine is rated 105 h.p. at 1800 r.p.m. The cylinder bore is 3.75 in. and the stroke 4.5 in., giving a displacement of 49.7 cu. in. per cylinder and a total displacement of 596.4 cu. in. Since the propeller is driven from the camshaft, its normal speed is 900 r.p.m. The dry weight is stated to be 345 lbs., hence the weight per rated h.p. is 3.28 lbs. The overall length is 42.125 in. and the overall width 34 in.

Fig. 54. Aster Airplane Engine.

ASTER

The Aster was a four-cylinder vertical water-cooled engine produced in England during 1910. The bore and stroke were 130 mm. (5.12 in.) and 140 mm. (5.51 in.), respectively. The displacement per cylinder was 113.36 cu. in. and the total displacement 453.44 cu. in. At 1000 r.p.m. the engine was rated 51 h.p., representing a brake mean effective pressure of 88.8 lbs. per sq. in.

The cylinders were in block construction of the "L" head type, the valves being operated directly through tappets. Magneto ignition was provided. The dry weight stated to be 242 lbs. shows 4.75 lbs. as the weight per horsepower.

ATWOOD

The Atwood Aeronautic Company of Williamsport, Pa., built airplane engines during 1915 and 1916 from the designs of Mr. Harry N. Atwood. The only model known to have been built by this firm was a twelve-cylinder 60 degree Vee type water-cooled engine stated to develop 120 h.p. at 2000 r.p.m., 150 h.p. at 2500 r.p.m., and 190 h.p. at 3200 r.p.m. The engine was known as Model 12-180. The bore and stroke were 3.5 and 4.5 in., respectively, and the total displacement was 519.54 cu. in. The speed of the propeller was reduced one-half that of the crankshaft by gearing.

Fig. 55. Atwood Aeronautic Engine.

The fuel consumption was approximately .65 lbs. per h.p-hr. A circular manifold connecting all cylinders was fed by two carburetors. An oil pressure of about 60 lbs. was maintained by a bronze gear pump in conjunction with a constant level splash system. The cooling water was circulated by a pump using bronze gear wheels, and dual ignition was provided by two twelve-cylinder Splitdorf magnetos.

The cylinders were individual castings of gray iron with separate cast-iron heads. The 1.75 in. valves were located in the cylinder head and operated by means of push rods from a camshaft mounted in the Vee. The crankshaft was a six-throw seven-bearing type. Pistons were made of aluminum and had three rings. The dry weight was stated to be 580 lbs.

and with a starter 650 lbs. The approximate overall dimensions are: length 48 in., height 27 in., and width 26 in.

AUSTIN

The Austin Motor Company of England built Sunbeam "Arab I" engines during the last eighteen months of the war and for a short time prior to this built R. A. F. la engines. They reconstructed Curtiss OX engines for Government use; and their own designs include a twelve-cylinder water-cooled Vee type, and an air-cooled rotary, having cast-iron cylinders, constructed about 1915.

AUSTRO-DAIMLER

The Austro-Daimler engines were originally built in Austria from the designs of Herr Porsche and later produced in Scotland by Arrol Johnston of Dumfries, and William Beardmore and Son of Glasgow. The latter firms have improved the design and continued to build the six-cylinder engines under the name of Beardmore.

The Austro-Daimler was one of the first airplane engines to attain any marked degree of success. Prior to the war it had been adopted for both airplane and dirigibles by the British, Russian, Italian, Austrian, and German armies.

Numerous early records were made by airplanes equipped with Austro-Daimler engines. The six-cylinder 120-h.p. engine was used in a Cody biplane, which won the £5000 prize during the British military trials of 1912. Oelerich broke the world's altitude record in July, 1914, at Leipzig, by climbing to 24,800 ft. in an all-steel military D. F. W. biplane fitted with a 120-h.p. Austro-Daimler engine. During the war the 200-h.p. engine was used in the Austrian "Berg" Scout.

All Austro-Daimler engines are water-cooled and arranged for direct driven propeller. With the exception of Type D-35, vertical four and six-cylinder forms are used entirely. Retaining and perfecting the principle features of a simple sturdy design no doubt accounts for the excellent results which have been obtained with Austro-Daimler engines.

40-h.p. The first four-cylinder Austro-Daimler engine was rated 40 h.p. at 1450 r.p.m., and gave as maximum output approximately 48 h.p. The cylinder bore was 100 mm.

(3.94 in.) and the stroke 120 mm. (4.72 in.). The displacement per cylinder was 57.55 cu. in. and the total displacement 230.2 cu. in.

The fuel consumption was stated to be .54 lbs. per h.p-hr., and the oil consumption .025 pts. per h.p-hr. An automatic carburetor, with rotary sleeve and fitted with a hot water jacket, furnished the mixture. Pressure lubrication was supplied by valveless piston pumps made under the Friedman patents. These were individual high pressure metering pumps supplying fresh oil only to the bearings.

Individual cast-iron cylinders, having electrolytically deposited copper water jackets, were offset from the crankshaft centerline. Single inlet and exhaust valves located in the cylinder head were operated from a single rocker arm controlled by two cams. Laminated leaf springs which oscillated with the rocker arm served to hold the valves to their seats.

Fig. 56. Exhaust Side of Austro-Daimler 40-h.p. Engine.

The crankshaft was an ordinary four-throw five-bearing type supported by individual bearing caps. The body of the connecting rod was of "H" section, and the light pressed steel pistons were fitted with three rings. Dual ignition was supplied by a Bosch magneto, and for cranking purposes the engine was equipped with an electric starter. The dry weight has been stated to be 165 lbs., or 4.1 lbs. per rated h.p. Including the radiator the weight was approximately 180 lbs.

65-h.p. The larger four-cylinder vertical Austro-Daimler engine was rated 65 h.p. at 1350 r.p.m., but actually developed more than 70 h.p. at this speed. The bore was 120 mm. (4.72 in.) and the stroke 140 mm. (5.51 in.), giving a displacement of 96.41 cu. in. per cylinder and a total displacement of 385.64 cu. in. At the rated output the brake mean effective pressure was approximately 99 lbs. per sq. in. At 1330 r.p.m. the fuel consumption was stated to be .517 lbs. per h.p-hr., and the oil consumption .018 lbs. per h.p-hr.

In general the construction of this engine was the same as the 40-h.p. model except that the cylinders were made with either copper or sheet-steel water jackets. Dual ignition was supplied by a Bosch high tension magneto with supplementary accumulator ignition and double distributor. The dry weight was stated to be 232 lbs., or 3.58 lbs. per rated h.p. The weight of the engine with radiator was stated to be 255 lbs.

Fig. 57. Austro-Daimler Four-Cylinder 65-h.p. Engine.

90-h.p. This engine had six cylinders exactly like those used on the 65-h.p. engine. The total displacement was 578.46 cu. in., the engine being rated 90 h.p. at 1300 r.p.m. and giving 100 h.p. at maximum recommended speeds.

The fuel consumption was .51 lbs. per h.p-hr., and the oil consumption .03 lbs. per h.p-hr. Two carburetors of the same principle as those used on the four-cylinder engines were attached to separate manifolds feeding three cylinders each. A

six-throw seven-bearing crankshaft was used, otherwise the design was practically identical to the smaller engine.

The dry weight was stated to be 316 lbs., or 3.51 lbs. per rated h.p. The weight of the engine with radiator was given as approximately 360 lbs. The overall dimensions were as follows: length 1226 mm. (48.6 in.), width 461.5 mm. (18.1 in.), height 690 mm. (27.2 in.)

Fig. 58. The Austro-Daimler 90-h.p. Engine.

120-h.p. This engine had six vertical cylinders of 130 mm. (5.12 in.) bore and 175 mm. (6.89 in.) stroke, and was rated 120 h.p., but later developed 140 h.p. at 1200 r.p.m. The total displacement was 850.5 cu. in. The consumption of fuel ranged from .51 to .54 lbs. per h.p-hr., and the oil consumption was approximately .03 lbs. per h.p-hr.

Fig. 59. Inlet Side Austro-Daimler 120-h.p. Engine.

Fig. 60. Exhaust Side, Austro-Daimler 120-h.p. Engine.

In general the design was quite similar to the earlier models. The inlet valve seated in a separate caging which could be removed for grinding the valve seat. The dry weight of this engine was somewhat over 450 lbs., and with radiator approximately 575 lbs.

200-h.p. The later and more refined six-cylinder Austro-Daimler engine, which appeared during the war, is the 200-h.p. model. This engine developes its rated power at 1400 r.p.m. and at recommended maximum speed (1600 r.p.m.) developes 222 h.p. The normal brake mean effective pressure is 123.3 lbs. per sq. in.

The bore is 135 mm. (5.31 in.) and the stroke 175 mm. (6.89 in.), giving a displacement per cylinder of 152.58 cu. in. and a total displacement of 915.48 cu. in. The compression ratio is 5.02 to 1. The fuel consumption is stated to be .499 lbs. per b.h.p-hr., and the oil consumption .039 lbs. per h.p-hr. One Duplex Austro-Daimler carburetor having a 24 mm. choke supplies the mixture. Lubrication is provided by one plunger pump delivering 5 lbs. pressure while operating at 1.15 times crankshaft speed.

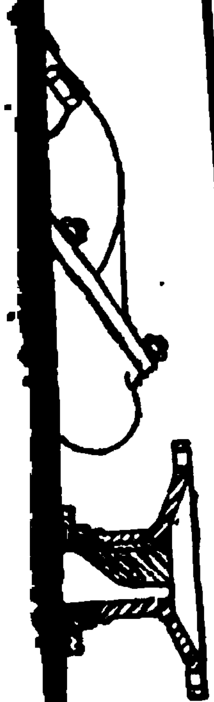
The cylinders are made from steel forgings machined all over and fitted with pressed steel water jackets welded in

Fig. 61. Induction Side of Austro-Daimler 200-h.p. Engine.

place. There are two inlet and two exhaust valves per cylinder, each having 44 mm. (1.73 in.) clear diameter and 45 degree seats. The inlet valve lift is 9.9 mm. (.39 in.) and the exhaust valve lift 10.16 mm. (.40 in.). The exhaust valves open into a common port, while one of the inlet valves seats in a caging which permits the removal of the other valves without

No. 62. Exhaust Side of Austro-Daimler 200-h.p. Engine.

Fig. 63. Transverse Section of Austro-Daimler 200-h.p. Engine.



lifting a cylinder. The valve timing is as follows: inlet opens 10 degrees early and closes 30 degrees late, exhaust opens 45 degrees early and closes 7 degrees late. The firing order 1-5-3-6-2-4 is common to most six-cylinder engines.

The crankshaft is a six-throw seven-bearing type weighing 96.5 lbs. The body of the connecting rod is of "H" section and the cap is held in place by four bolts. Aluminum pistons are employed, these being fitted with three rings, all of which are located above the wrist pin.

A centrifugal water pump operating at 1.894 crankshaft speed is mounted in a rather unusual manner at the anti-propeller end of the engine. Unlike most overhead camshaft drive arrangements, this one is located at the propeller end. From this driveshaft are driven two Bosch Z-H-6 magnetos, mounted diagonally to the center line of the engine. Two spark plugs are located on the inlet side of each cylinder.

The dry weight including the propeller hub and exhaust manifold is 728.5 lbs., or 3.64 lbs. per h.p. Including the cooling system the engine weighs 858.5 lbs., or 4.29 lbs. per h.p. The overall dimensions are as follows: length 67.875 in., width 22.375 in., and height 45.25 in.

400-h.p. The 400-h.p. Austro-Daimler engine, known as Type D-35, has twelve cylinders arranged in the usual 60 degree Vee form. Being a two-fold likeness of the 200-h p. engine, the total displacement is therefore 1830.96 cu. in.

The carburetors are placed on the outside of the cylinders instead of the usual location in the Vee. Two pumps are used

Fig. 65. The Austro-Daimler 400-h.p. Engine.

to furnish forced lubrication. The engine is provided with two water pumps, each of which circulates the water through one bank of cylinders. The connecting rods have "H" sections, and are of the articulated type. Dual ignition is supplied by two Bosch twelve-cylinder magnetos, each being driven from one of the vertical camshaft drive shafts.

A 360-h.p. Austro-Daimler water-cooled six-cylinder vertical engine for dirigible use has a 180 mm. (7.09 in.) bore and stroke, and a total displacement of 1679.52 cu. in. The individual cylinders are of built up steel and welded construction and have four inclined valves in the head that are operated through rockers from an overhead camshaft.

AZTATL

The Aztatl, the first airplane engine constructed in Mexico, was built for the first time in February, 1917, under the direction of Colonel Alberto Salinas in cooperation with Dr. Francisco Santarini. The engine was originally used for school work, but later gave quite satisfactory results in exhibition flights. The Aztatl engines are all radial air-cooled types and quite similar in design to the well-known Anzani engines. In addition to the six-cylinder Aztatl engine described below there have also been built three and ten-cylinder models.

Six-Cylinder. The six-cylinder Aztatl engine, which was rated normally 80 h.p. at 1200 r.p.m., had a bore of 115 mm. (4.53 in.), a stroke of 140 mm. (5.51 in.), and a total displacement of 532.36 cu. in. The corresponding brake mean effective pressure would be nearly 100 lbs. per sq. in. It is stated that the fuel consumption was .71 lbs. per h.p-hr., and the total weight 324 lbs., or 4.05 lbs. per rated h.p.

The cylinders had integral cooling fins and were made from steel castings. There was one inlet and one exhaust valve per cylinder, the inlet being automatic in operation and the exhaust opened by means of a push rod and rocker arm. The two-throw crankshaft was supported on large radial ball bearings. The connecting rods, which were tubular in section, were attached to the cast-iron piston by two bolts. Lubricating oil was fed to the bearings under pressure from a two-pistoned pump. Single ignition was supplied by a high tension magneto.

Fig. 66. Aztatl Radial Engine.

BASSÉ-SELVE

The engines manufactured by Bassé and Selve of Altena, Westphalia, are six-cylinder water-cooled vertical types, of construction typical to most German designs.

One of the earlier Bassé-Selve designs had a 125 mm. (4.92 in.) bore, 160 mm. (6.3 in.) stroke, and a total displacement of 718.62 cu. in. The engine was rated at 120 h. p., but is said to have developed normally 130 h.p. at 1380 r.p.m. and 145 h.p. at 1450 r.p.m. The propeller speed was reduced by gearing. The dry weight was stated to be 430 lbs., or 3.58 lbs. per rated h.p.

The cylinder heads were cast in pairs from iron and had

Fig. 67. Inlet Side of 270-h.p. Bassé-Selve Engine.

steel sleeves inserted. The overhead camshaft and valve mechanism were so designed that it was possible to remove valves without disturbing a cylinder. The pistons were made from aluminum. Two Z-H-6 Bosch magnetos supplied the ignition, and two Zenith carburetors the mixture. A special valveless piston pump circulated the oil and added a sufficient quantity of fresh oil to the system to replace the amount used. A complete lubricating system was provided for the camshaft.

The six-cylinder engine rated at 270 h.p. was a larger model of practically the same design. This engine had a 160 mm. (6.3 in.) bore, 200 mm. (7.87 in.) stroke, and a total displacement of 1471.98 cu. in. At 1450 r. p. m. the engine is said to have developed 300 h.p. The dry weight was stated to be 882 lbs., or 3.27 lbs. per rated h.p.

A later Bassé-Selve design, used by the Germans during the war, had a 155 mm. (6.1 in.) bore and 200 mm. (7.87 in.) stroke. This engine developed normally approximately 269 h.p. at 1400 r.p.m. and 300 h.p. at 1600 r.p.m., the maximum recommended speed. The total displacement was 1381.28 cu. in., and the compression ratio approximately 4.34 to 1. The dry weight was stated to be 885 lbs.

Fig. 69. Transverse Section, Bassé-Selve 300-h.p. Engine.

The cylinders were of individual construction, steel barrels being screwed and welded into cast-steel heads. The two inlet and two exhaust valves per cylinder, which were inclined

to the vertical axis, each had 45 degree seats, a clear diameter of 2.2 in., and a lift of .39 in. The camshaft was located overhead and the cams operated against stirrups which encircled them. These in turn acted upon rocker arms which were mounted on ball bearings. Compression relief cams were provided for starting purposes.

The crankshaft was an ordinary six-throw seven-bearing type and weighed 138.5 lbs. The connecting rods had tubular sections and four-bolt caps. The pistons were made of aluminum and employed four rings, three of which were located above the wrist pin.

The mixture was supplied by two double feed carburetors having 50 mm. chokes, 2.59 mm. main jets and 1.17 mm. pilot jets. Pressure lubrication was maintained by a duplex double-acting plunger pump, and dual ignition was provided by two Bosch Z-H-6 magnetos.

BATES

The Bates engine was built in England during 1909 and 1910. There were four vertical water-cooled cylinders of 101 mm. (3.98 in.) bore and stroke with a displacement of 49.51 cu. in. The total displacement was 198 cu. in., and the engine developed from 28 to 30 h.p. at normal operating speeds. The stated dry weight (116 lbs.), considering the output and type of engine, shows a remarkably low value of about 4 lbs. per h.p.

BAYERISCHE

The Bayerische Motoren Gesellshaft of Germany have built air-cooled rotary engines patterned closely after the French Gnome designs. One of their early seven-cylinder models was rated 50 h.p. at 1200 r.p.m. The bore was 110 mm. (4.33 in.), the stroke 120 mm. (4.73 in.), and the total displacement 487.55 cu. in.

The Bayerische engine differed from the Gnome in that two piston inlet valves were used instead of one. The valve operating mechanism was also changed. The cylinders were held down by split U-shaped clamping rings which fitted over corresponding flanges on cylinder and crankcase.

Fig. 70. The Bayerische Rotary Engine.

BEARDMORE

The British built Beardmore engines are refined versions of the early Austro-Daimlers, which at one time were recognized by many as the most efficient airplane engines in existence. Arrol Johnston and William Beardmore and Son are the best known among the various firms which have constructed Beardmore engines and parts.

The 90 and 120-h.p. models were perhaps the only types built up to 1916 when the requirements then made it imperative to develop a larger engine. Arrol Johnston, Ltd., of Dumfries, Scotland, undertook the development of the 160-h.p. Beardmore engine and afterwards concentrated on its manufacture. Although not an exact copy of any Austro-Daimler model, the 160-h.p. Beardmore engine still retained the prin-

cipal features and the same general form of construction as the earlier designs.

90-h.p. Corresponding to the Austro-Daimler engine from which this design originated, the bore and stroke were 120 mm. (4.72 in.) and 140 mm. (5.51 in.) respectively, and the total displacement was 578.46 cu. in. There were six separate water-cooled cylinders in vertical arrangement developing 90 h.p. at 1300 r.p.m. The consumption of fuel was stated to be .54 lbs. per h.p-hr., and the oil consumption .028 lbs. per h.p-hr.

120-h.p. This was a six-cylinder vertical water-cooled engine of 130 mm. (5.12 in.) bore, 175 mm. (6.89 in.) stroke, and a total displacement of 850.5 cu. in. Although rated at 120 h.p. the engine was said to actually develop 135 h.p. at 1200 r.p.m. The consumption of fuel was stated to be .54 lbs. per h.p-hr., and the consumption of oil .028 lbs. per h.p-hr.

The cylinders were offset from the centerline of the crankshaft 18 mm. They were cast from iron and provided with steel flanges and electrolitically deposited copper water jackets. Both valves were operated from one tappet rod and held to their seats by laminated leaf springs, a salient feature of all Beardmore engines. The exhaust valve seated in the cylinder proper, while the inlet valve seated in a removable valve caging. The inlet valve opened 27.5 degrees late and closed 37 degrees late; the exhaust valve opened 44 degrees early and closed 2.5 degrees early.

Fig. 71. End View Beardmore 160-h.p. Engine.

The six-throw crankshaft was mounted in nine plain bear-

ings. The connecting rods were of "H" section and had four-bolt caps. The pistons were made of steel and fitted with three rings.

The mixture was furnished by two Beardmore type carburetors feeding three cylinders each. A Bosch lubricator with six plungers provided forced lubrication to the main bearings, while the big end of the connecting rods were lubricated by splash. Water was circulated by a centrifugal pump, and dual ignition was supplied by H-L-6 type magnetos. The engine was also equipped with one starting magneto. The dry weight was stated to be 545 lbs.

160-h.p. The larger six-cylinder vertical water-cooled Beardmore engine, rated at 160 h.p., is said to have developed 180 h.p. at 1400 r.p.m. The bore is 142 mm. (5.59 in.), the stroke 175 mm. (6.89 in.), and the total displacement 1014.54 cu. in. The fuel consumption is stated to be .52 lbs. per b.h.p-hr., and the oil consumption .03 lbs. per b.h.p-hr.

The design and construction of this engine is practically the same as the smaller models. The valve timing is as follows: inlet opens 26 degrees late and closes 36.75 degrees late; exhaust opens 45.25 degrees early and closes 4 degrees early. The total dry weight was said to be 600 lbs., and the weight of the water carried in the cylinder jackets 4 lbs. 7 oz.

BEATTY

The first Beatty engines were produced in 1914. These and the subsequent improved models were used mostly at the Beatty School of Flying, Ltd., Cricklewood, London, N.

40-h.p. The original Beatty engine was a four-cylinder vertical water-cooled type of 4.375 in. bore, 4 in. stroke, and 240.52 cu. in. total displacement. The engine was rated 40 h.p. at 1450 r.p.m., corresponding to 89 lbs. per sq. in. b.m.e.p. In this model the inlet valves were operated automatically, and the connecting rods were made with tubular sections. The dry weight stated to be 180 lbs., or 4.5 lbs. per rated h.p.

80-h.p. An eight-cylinder 90 degree Vee type engine, using the same cylinders as the smaller model, was rated at 80 h.p. The total displacement was therefore 481. cu. in. The dry weight, including the flywheel, was stated to be 280 lbs., or 3.5 lbs. per rated h.p.

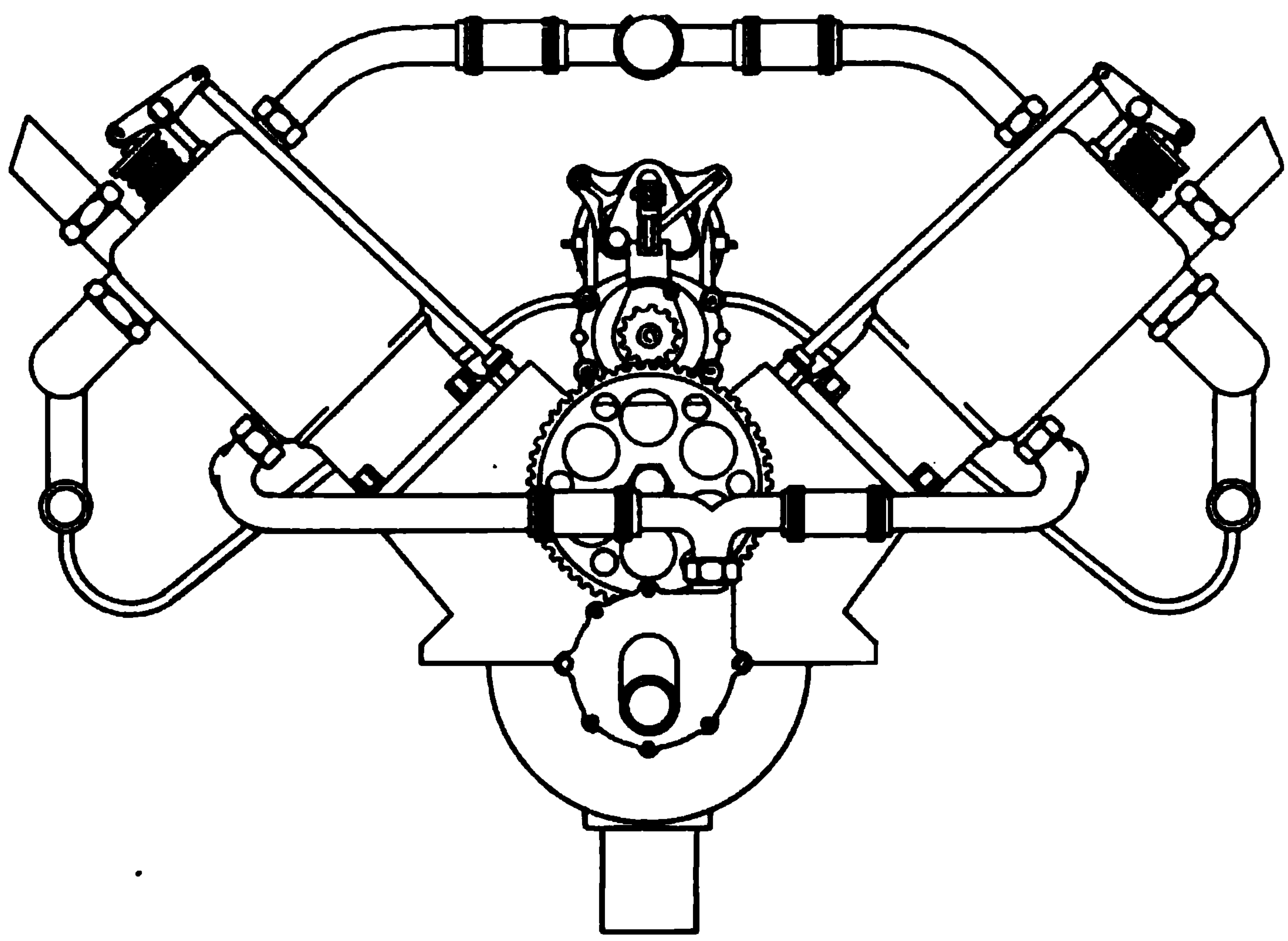


Fig. 72. The Beatty Eight-Cylinder Engine.

50-h.p. A larger four-cylinder vertical water-cooled engine of 4.375 in. bore, 4.5 in. stroke, and 270.6 cu. in. total displacement, was rated 50 h.p. at 1600 r.p.m. The consumption of fuel was stated to be 308 lbs. per hr., and the dry weight 248 lbs., or 4.97 lbs. per rated h.p.

The crankshaft was fitted with a flywheel and at the opposite end with a sprocket for chain drive to a propeller. The connecting rods were of "H" section, and the internally ribbed cast-iron pistons were fitted with three top rings. A plunger type oil pump fed oil into a tube with holes to spray the big end of the rod while the wrist pin and piston were lubricated by splash in the usual manner.

In this model both valves were mechanically operated. They were located overhead and operated by means of push rods and rocker arms. Originally this engine was built with separate cast-iron cylinders having steel water jackets shrunk on. Another design of the same size was later brought out with the cylinders cast in one block. This proved to be 5 lbs. lighter and somewhat shorter in overall length.

60-h.p. A geared Beatty engine having four vertical water-cooled cylinders was produced with 4.375 in. bore, 5 in. stroke, and 300.66 cu. in. total displacement. A plain type gear reduction having a ratio of 2 to 3 was used.

The four cylinders including the water jackets were cast en bloc from iron. The valves were located overhead and operated through push rods in the same manner as other Beatty models. Forced lubrication was maintained by a gear pump. Claudel-Hobson carburetors furnished the mixture, and Dixie magnetos the ignition.

As in the case of the 50-h.p. Beatty engine, an earlier model of the same dimensions, but with individual cylinders, was produced.

Fig. 73. Transverse Section, Beatty Four-Cylinder Engine.

BECK

The Beck was an unconventional type rotary engine built in England during 1910. In this engine the pistons oscillated in an annular formed cylinder of approximately 30 in. diameter. The construction of such a type is extremely difficult.

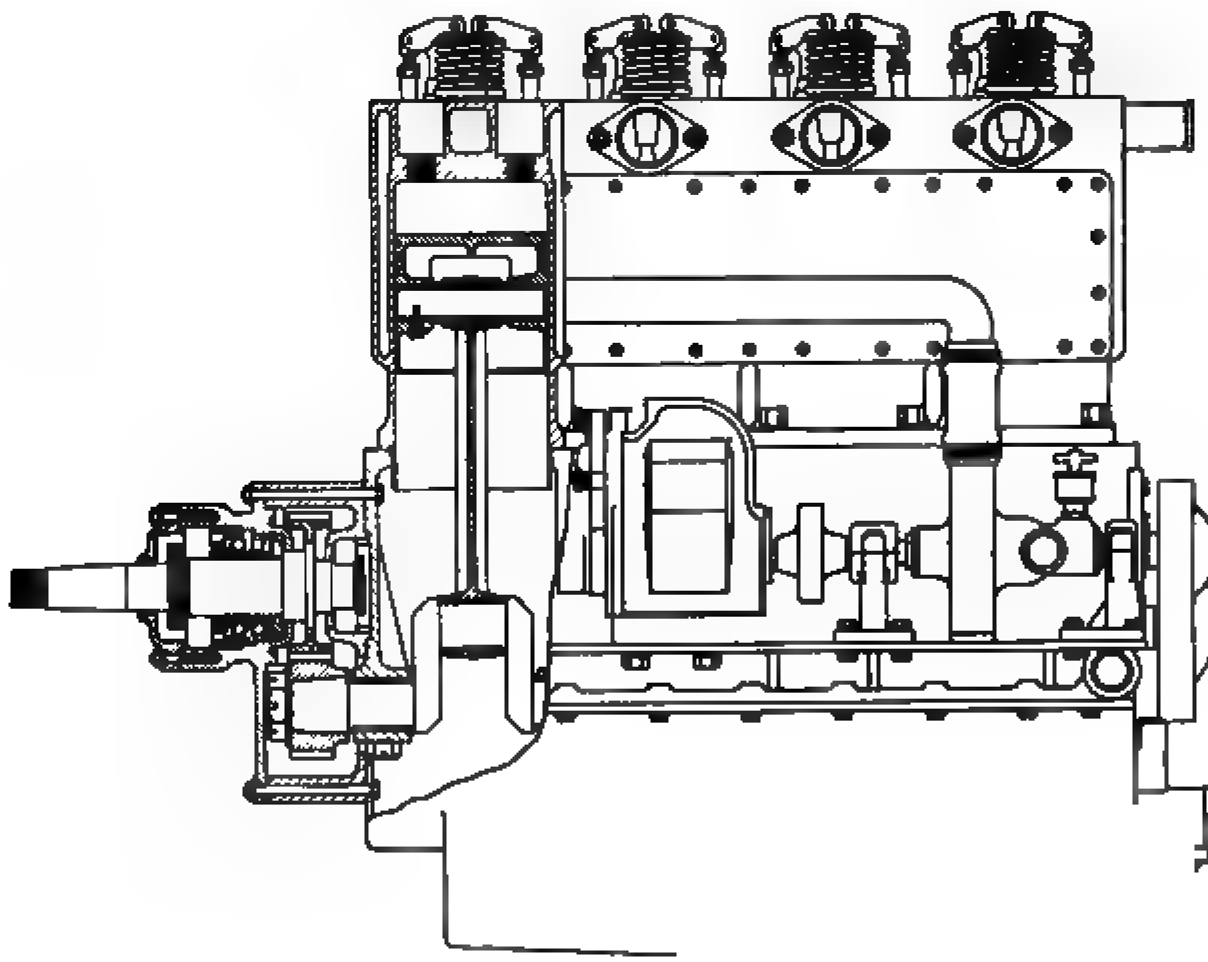


Fig. 74. The Beatty Geared Engine.

BEECHER

The B. L. Beecher Company of New Haven, Connecticut, produced an eight-cylinder air-cooled horizontally-opposed type airplane engine during 1919

Fig. 75. Beecher Eight-Cylinder Engine.

BENTLEY

The Humber Company of Coventry, England, was the first to build the Bentley Rotary or B.R.-1 engine. This engine was designed by Capt. W. O. Bentley during the early part of the war with the object of obtaining a lighter and more efficient rotary engine than the Clerget which was then so widely used in British aircraft. The weight saving was effected by careful design and the use of aluminum wherever possible. Following the development of the B.R.-1 engine there was brought out a larger model known as the B.R.-2, the manufacture of which was also taken up by other British firms.

Fig. 76. B. R.-1 Rotary Engine.

B.R.-1. The B.R.-1 was a nine-cylinder air-cooled rotary engine of 120 mm. (4.72 in.) bore, 170 mm. (6.69 in.) stroke, and a total displacement of 1053.09 cu. in. This engine was rated at 150 h.p , but was said to actually develop 154 h.p. at 1250 r.p.m. and 156 h.p. at 1300 r.p.m. The compression ratio was 5.9 to 1.'

The fuel consumption was stated to be .59 lbs. per h.p-hr., and the oil consumption .10 lbs. per h.p-hr. One carburetor of the block tube type was employed, and pressure lubrication was maintained by a plunger oil pump. Ignition was provided by two A.D.S. magnetos. The dry weight was stated to be 405 lbs., or 2.67 lbs. per rated h.p.

B.R.-2. The B.R.-2 is a nine-cylinder air-cooled rotary engine of 140 mm. (5.51 in.) bore, 180 mm. (7.09 in.) stroke, and a total displacement of 1522.44 cu. in. The compression ratio may range from 5 to 5.2. Rated at 200 h.p., the engine is said to actually develop from 230 to 250 h.p. at 1300 r.p.m. The fuel consumption is stated to be .63 lbs. per effective h.p-hr., and the oil consumption .094 lbs. per effective h.p-hr. The carburetor is of the block tube mixing valve type with a 64 mm. choke and 4.25 mm. jet.

The crankcase is machined from a large forged steel ring. The cylinders, which are held down by long bolts from lugs on the detachable heads, have barrels cast from aluminum with steel liners shrunk into place.

The Clerget type of annulus valve gear is employed. There is one inlet and one exhaust valve per cylinder, each with 30 degree seats. The clear diameter of the inlet valve is 52 mm. (2.047 in.) and the lift 12 mm. (.4724 in.). The clear diameter of the exhaust valve is 58 mm. (2.284 in.) and the lift 13.5 mm. (.531 in.). The inlet valve opens at top dead center and closes 58 degrees late; the exhaust valve opens 72 degrees early and closes 10 degrees late.

The single throw crankshaft is built up in three sections. The connecting rods are of the articulated type and all have tubular sections. The master rod, which is mounted on ball bearings, is similar in construction to those used on the Gnome engines. The pistons are made from aluminum, ribbed inside, and fitted with five rings. Dual ignition is supplied by M-L magnetos running at 2.25 times crankshaft speed.

The approximate dry weight of the engine is 500 lbs., which at maximum output represents 2 lbs. per h.p. The overall diameter is 42 in. and the distance from the front support to the front of the propeller hub is 24.3125 in. The rear support is located 13 in. behind the front support.

Fig. 77. End View, B. R.-2 Engine.

Fig. 78. Side View, B. R.-2 Engine.

BENZ

Benz and Cie (Rheinische Automobil and Motorenfabrik A. G.) of Mannheim, Germany, who had already become well known through their famous racing cars, first gained recognition as constructors of airplane engines by winning First Prize in the Kaiser Prize Contests held during July, 1912. The Benz engines have always been close competitors of the well-known Mercedes. Being typical of German construction they were confined entirely to the vertical types until late during the war, when the development of eight and twelve-cylinder Vee types was undertaken. The requirements of larger power units would no doubt have brought these engines into use before the end of hostilities had not the German resources been so limited.

All Benz engines bear a certain resemblance. The over head valves are operated through push rods and rockers, and the separate cylinders are made with sheet metal water jackets welded to either a cast-iron cylinder or to a cast-head cylinder with screwed in steel barrel. As a rule these engines were sturdily constructed and quite heavy for the power output, but were featured in their reliability and ease of upkeep.

The engine which won the Kaiser prize was a four-cylinder vertical water-cooled type of 130 mm. (5.12 in.) bore, 180 mm. (7.09 in.) stroke, and 583.48 cu. in. total displacement. The engine was stated to develop 103 h.p. at 1288 r.p.m., and weigh 345 lbs., or 3.34 lbs. per rated h.p. The fuel consumption has been reported as .465 lbs. per h.p-hr., and the oil consumption .044 lbs. per h.p-hr. The cylinders were made separately from cast-iron with welded steel water jackets, and offset from the crankshaft center line 20 mm. The general form of construction was closely followed in some of the later and more refined six-cylinder Benz engines.

Fig. 79. Benz 100-h.p. Four-Cylinder Engine.

Fig. 80. Camshaft Side of Benz Four-Cylinder Engine.

Type F-B. This was a six-cylinder vertical water-cooled engine of 106 mm. (4.17 in.) bore, and 150 mm. (5.91 in.) stroke, having a total displacement of 484.26 cu. in. The engine was rated at 85 h.p., and reported to have developed 88 h.p. at 1250 r.p.m. and 95 h.p. at 1350 r.p.m. At the higher speed the brake mean effective pressure would be 115 lbs. per sq. in. The fuel consumption ranged from .48 to .53 lbs. per h.p-hr., and the oil consumption was .022 lbs. per h.p-hr.

The mixture was furnished by two Benz carburetors attached to the crankcase, the air being drawn to the carburetors through passages in the crankcase. The cooling water was circulated by a centrifugal pump, the water pipe entering the lower half and coming up through the top half of the crankcase at the center where branches led to each side for three cylinders. A force feed system of lubrication was used, and dual ignition was supplied by two magnetos. The weight was stated to be 365 lbs., or 4.3 lbs. per rated h.p.

The cylinders were offset from the crankshaft center line 18 mm. These were cast individually from iron and had sheet steel water jackets welded in place. The crankshaft was a seven-bearing type, and the piston material was cast iron.

Type F-D. This was a six-cylinder vertical water-cooled engine of 116 mm. (4.57 in.) bore, 160 mm. (6.30 in.) stroke, and 620.04 cu. in. total displacement. The horsepower developed was stated to be 108 at 1250 r.p.m., 110 at 1300 r.p.m.,

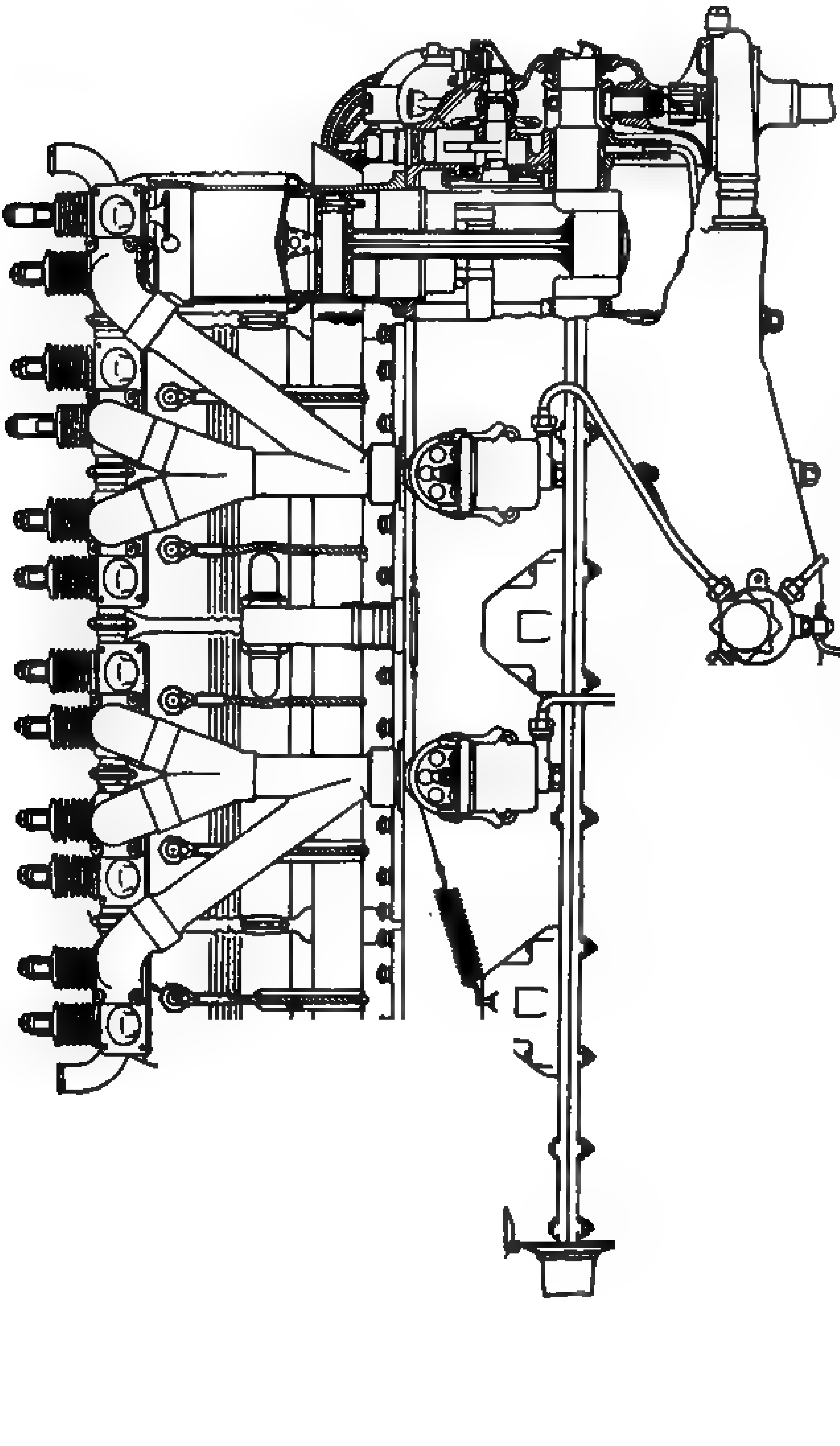


Fig. 81. Side and Section, Benz 160-h.p. Engine.

and 115 h.p. at 1350 r.p.m. The fuel consumption was said to be .506 lbs. per h.p-hr., and the oil consumption .022 lbs. per h.p-hr. The dry weight was 425 lbs. Cylinders of the usual Benz form of construction were mounted offset from the crankshaft center line 20 mm.

Type F-F. This was a six-cylinder vertical water-cooled engine of 130 mm. (5.12 in.) bore, 180 mm. (7.09 in.) stroke,

Fig. 82. Transverse Section, Benz 160-h.p. Engine.

and 875.22 cu. in. displacement. The compression ratio was 4.5 to 1. The engine was rated normally 160 h.p. at 1400 r.p.m. The fuel consumption ranged from .50 to .52 lbs. per h.p-hr., and the oil consumption was .03 lbs. per h.p-hr. Two carburetors of Benz design furnished the mixture, and dual ignition was supplied by two Bosch Z-H-6 magnetos. An oil pressure of approximately 60 lbs. was maintained at the bearings.

The usual individual cast-iron cylinders with welded on steel water jackets were offset from the crankshaft center line 20 mm. The valves were located in the cylinder head and operated through push rods, and rockers which were mounted on ball bearings. The clear diameter of both the inlet and exhaust valves was 61.5 mm. (2.42 in.) and the lift 11 mm. (.443 in.). The inlet valve opened at top center and closed 60 degrees late; the exhaust opened 60 degrees early and closed 16.5 degrees late. The crankshaft was a seven-bearing type, the connecting rods had tubular sections, and the cast-iron pistons were fitted with three rings. The dry weight of the engine was stated to be 475 lbs.

230-h.p. This was a six-cylinder vertical water-cooled engine 145 mm. (5.71 in.) bore, 190 mm. (7.48 in.) stroke, and 1149.24 cu. in. total displacement. The compression ratio was 4.91 to 1. The engine developed its rated horsepower at 1400 r.p.m. and its maximum of 250 h.p. at 1650 r.p.m. The normal brake mean effective pressure at 1400 r.p.m., was 113 lbs. per sq. in., and the maximum which occurs at 1100 r. p.m. 119 lbs. per sq. in.

The fuel consumption was reported to be .59 lbs. per b.h.p-hr., and the oil consumption .023 lbs. per b.h.p-hr. The mixture was furnished by two Benz carburetors each feeding three cylinders, the air entering the carburetor intake being received from a passage through the crankcase. A normal oil pressure of 28 lbs. was maintained by a high speed gear pump working in the sump. The centrifugal water pump operated at 1.58 crankshaft speed, and dual ignition was furnished by Z-H-6 Bosch magnetos.

The individual cylinders were of cast-iron construction and had sheet-steel water jackets welded in place. The overhead valves were operated by push rods on either side of the

engine. The valve tappets were rollers mounted upon eccentrics which provided an easy means of adjusting the tappet clearance. There were two inlet and two exhaust valves per cylinder, each with a clear diameter of 52 mm. (2.047 in.). The inlet valve lift was .465 in. and the exhaust valve lift .443 in. The inlet valve opened 10 degrees early and closed 55 degrees late; the exhaust valve opened 60 degrees early and closed 20 degrees late.

Fig. 83. Benz 230-h.p. Engine.

The crankshaft was an ordinary six-throw type mounted in seven plain bearings. The connecting rods had tubular sections and employed four-bolt caps. The pistons were cast from iron, and the piston head was supported by a conical steel forging bearing on the piston pin. Three wide rings were fitted at the top.

Fig. 84 Transverse Section, Benz 230-h.p. Engine.

The dry weight was stated to be approximately 863 lbs., or 3.68 lbs. per rated h.p. The water carried in the jackets weighed 30.9 lbs. The overall dimensions were as follows: length 59 in., width 20.9 in., and height 51.7 in.

Type Bz-3AV. One of the Benz engines used by the Germans during the latter part of the war had six vertical water-cooled cylinders of 140 mm. (5.51 in.) bore, 190 mm. (7.48 in.) stroke, and 1070.16 cu. in. total displacement. The normal output at 1400 r.p.m. is 221.5 h.p. and the maximum at 1600 r.p.m. is 239 h.p. At normal speeds the brake mean effective pressure is 117 lbs. per sq. in., and at maximum speeds 110 lbs. per sq. in. The compression ratio is 5.8 to 1.

The fuel consumption is stated to range from .474 to .491 lbs. per b.h.p-hr. The mixture is furnished by two Benz Bz-3-A-137 carburetors, having .42 mm. (1.654 in.) chokes and main jets of 1 mm. (.039 in.). Lubrication is of the dry sump type. A gear pump delivers approximately 23 lbs. pressure, to the bearings, and a six vane centrifugal pump of approximately 4.5 in. diameter delivers water to the cylinder jackets through two outlets. Dual ignition is supplied by Bosch Z-H-6 magnetos.

The individual cylinders of steel barrels screwed into cast-iron heads are encased by sheet-steel water jackets which are

Fig. 86. Intake Side, 200-h.p. Benz Engine.

welded in place. The overhead valves are operated through push rods and rocker arms having eccentric mountings for the rollers which act as tappets. There are two inlet and two exhaust valves per cylinder, each with a clear diameter of 1.693 in., a lift of .433 in., and 30 degree seats. The inlet valve opens 5 degrees late and closes 45 degrees late; the exhaust opens 55 degrees early and closes 18 degrees late.

The crankshaft is of the usual six-throw type mounted in seven plain bearings. The connecting rods have tubular sections and employ four-bolt caps. The aluminum pistons are ribbed inside and fitted with four rings.

Fig. 87. End View, 200-h.p. Benz Engine.

The dry weight of the engine is reported to be 638.2 lbs., or 2.88 lbs. per rated h.p., and the weight of the water carried in engine is 19 lbs. The approximate overall dimensions are as follows: length 51.5 in., width 21.5 in., and height 40 in.

195-h.p. There has been reported a 195-h.p. Benz model which is an eight-cylinder Vee type water-cooled engine of 125 mm. (4.92 in.) bore, 140 mm. (5.51 in.) stroke, and 838 cu. in. total displacement. The engine is stated to develop 225 h.p. at 1700 r.p.m.

Type Bz-3BV. Another eight-cylinder 90 degrees Vee type water-cooled Benz engine has 135 mm. (5.31 in.) bore and stroke, and 940.72 cu. in. total displacement. The engine is rated at 195 h.p., but is said to develop 200 h.p. at 1800 r.p.m. and 275 h.p. at 2000 r.p.m. This engine is fitted with a gear reduction having a ratio of 19 to 29, thus giving the propeller a normal speed of 1180 r.p.m.

The fuel consumption is reported to be .485 lbs. per b.h.p-hr. and the oil consumption .033 lbs. per b.h.p-hr. The

dry weight of the engine is stated to be 683 lbs., and the weight of the water carried in the engine 22 lbs.

Bz-4. This is a six-cylinder vertical water-cooled engine of 145 mm. (5.71 in.) bore, 190 mm. (7.48 in.) stroke, and 1149.24 cu. in. total displacement. The engine is rated 200 h.p., but is said to develop normally 225 h.p. at 1400 r.p.m. and 275 h.p. at 1500 r.p.m.

The fuel consumption is said to be .496 lbs. per h.p-hr., and the oil consumption .026 lbs. per h.p-hr. The dry weight is reported to be 816 lbs., or 4.08 lbs. per rated h.p., and the water content of the engine 28.6 lbs.

Fig. 88. End View, Benz Type Bz-3BV.

Bz-5B. This is a twelve-cylinder 60 degree Vee type water-cooled engine of 135 mm. (5.31 in.) bore, 150 mm. (5.91 in.) stroke, and 1570.56 cu. in. total displacement. The rated output is 300 h.p. at 1800 r.p.m. and 400 h.p. at 2000 r.p.m. An epicyclic type of gear reduction, having a ratio of 19 to 29, is fitted.

The fuel consumption is stated to be .496 lbs. per h.p-hr., and the oil consumption .026 lbs. per h.p-hr. The mixture is furnished by two duplex carburetors, each of which feed three cylinders, and dual ignition is provided by Bosch twelve-cylinder magnetos. Lubrication is on the dry sump principle, a gear pump being adjusted to deliver at no time less than 7.5 lbs. pressure to the bearings.

The individual cylinders are made up from steel barrels screwed into cast-iron heads and encased by sheet-steel water jackets welded in place. The camshaft is located centrally in the Vee, and operates one inlet and two exhaust valves in each of the cylinders through push rods and rockers.

The crankshaft is a six-throw seven-bearing type. The connecting rods are of the articulated type and have tubular sections. The aluminum pistons have eight ribs underneath the head and are fitted with four top rings and one lower scraper ring. The cooling water is circulated by a centrifugal pump with double outlets branching to the top and bottom of the end cylinders in each bank. The dry weight is stated to be 948 lbs., and water content of the engine is 35.3 lbs.

Fig. 89. End View, Benz 300-h.p. Engine.

Bz-5. A twelve-cylinder 60 degree Vee type water-cooled engine has 145 mm. (5.71 in.) bore, 170 mm. (6.69 in.) stroke, and 2055.72 cu. in. total displacement. The engine is rated at 300 h.p., and said to develop 320 h.p. at 1500 r.p.m. and 450 h.p. at 1700 r.p.m. The normal speed of the propeller is 985 r.p.m., being geared at a ratio of 17 to 29 crankshaft speed. The fuel consumption is stated to be .496 lbs. per b.h.p-hr., and the oil consumption .026 lbs. per h.p-hr. The dry weight is reported to be 1056 lbs., and the water content of the engine 39.7 lbs.

Bz-6. This is a twelve-cylinder 60 degree Vee type water-cooled engine of 145 mm. (5.71 in.) bore, 190 mm. (7.48 in.) stroke, and 2298.48 cu. in. total displacement. The engine is rated 500 h.p. at 1400 r.p.m. and 625 h.p. at 1600 r.p.m. This engine is made with a flange which allows for the attachment of a standard propeller reduction gear. The fuel consumption is said to be .496 lbs. per h.p-hr., and oil consumption .033 lbs. per h.p-hr. The dry weight is stated to be 1486 lbs., and the water content of the engine 72.7 lbs.

Fig. 90. Longitudinal Section of Benz 500-h.p. Engine.

There are four valves in each cylinder which are operated through push rods and rockers from one central camshaft, and two located on either side of the engine The crankshaft is a six-throw type mounted in seven plain bearings. The connecting rods are of the articulated type, the master rod having an "H" section and the linked rod a tubular section.

Fig. 91. End and Sectional Views of Benz 500- h.p. Engine.

Bz-6V. This is a twelve-cylinder Vee type water-cooled engine of 165 mm. (6.10 in.) bore, 200 mm. (7.87 in.) stroke, and 2760 cu. in. total displacement. The engine is rated 500 h.p., and said to develop 575 h.p. at 1500 r.p.m. and 675 h.p. at 1700 r.p.m. This model is also provided with a flange for attaching a standard propeller reduction gear.

The fuel consumption is stated to be .496 lbs. per h.p-hr., and the oil consumption .033 lbs. per h.p-hr. The dry weight is reported to be 1531 lbs., and the water content of the engine 77 lbs.

B. H. P.

The initials stand for the names of the designers, the original B. H. P. engine being designed by Major Halford in collaboration with Sir William Beardmore and Mr. T. C. Pullinger. The work, which was begun early in 1916, was for the purpose of developing a light high-powered six-cylinder engine which at that time was not available, but greatly needed by the British Air Service for use on the Western Front.

As time was an important factor, the Arrol Johnston Co., Ltd., immediately set about to enlarge the 120-h.p. Beardmore engine to give 160 h.p. or more. This larger engine proved successful and was quite extensively used in place of the 120-h.p. model. The design of the B. H. P. engine was continued, however, and the first engine was completed in June, 1916. The majority of British engine manufacturers were then busily engaged in important production, so a new company was formed to exploit the new B. H. P. design. Factories were built at Dumfries, Scotland, and the new company was known as the Galloway Engineering Co., Ltd. The B. H. P. design which they built was afterwards known as the Galloway "Adriatic."

After successful test on the first models, it was realized that the manufacturing facilities were not sufficient to produce the numbers required, so the Siddeley Deasy Co. of Coventry, England, now the Armstrong-Siddeley Motors, Ltd., was requested to take over the building of the B. H. P. engine. Production on a large scale was reached in a very short time. These engines, having been completely redesigned

by Siddeley-Deasy, afterwards became known as the "Puma" and were adopted as the standard six-cylinder vertical water-cooled engine by the Royal Air Force.

Both the Galloway and the Siddeley firms have built larger models patterned after the original B. H. P. designs. These are described elsewhere, together with descriptions of the "Adriatic" and "Puma" engines

BIANCHI

The Eduardo Bianchi Company of Milan, Italy, constructed Isotta-Fraschini engines of the V-4B type under license during the war.

Fig. 92. The Binetti Type B-300 Engine.

BINETTI

The Binetti engine, known as type B-300, was developed experimentally in France during the war. This was a six-cylinder vertical water-cooled engine of 130 mm. (5.12 in.) bore and 160 mm. (6.30 in.) stroke, having a total displacement of 777.66 cu. in. It has been erroneously reported that the engine developed 300 h.p. at a normal speed of 2000 r.p.m. and 315 h.p. at 2100 r.p m. A plain type gear reduction with helical gear teeth and having a ratio of .595 gave the propeller a normal speed of 1190 r.p.m.

The cylinders were constructed in blocks of three and offset from the crankshaft center line. Steel barrels were screwed into cast-iron heads and encased in an aluminum water jacket held in place by flanges. There were two inlet and two exhaust valves per cylinder that were operated by an overhead camshaft enclosed in an oil-tight housing.

The six-throw crankshaft had circular crank webs and was mounted on seven plain bearings. The connecting rods were of tubular section and had four-bolt caps. The aluminum pistons were fitted with three rings, two of which were located above the wrist pin. One duplex carburetor furnished the mixture, and dual ignition was provided by H-L-6 magnetos. A gear pump fed oil to the bearings under pressure. The weight was said to be 715 lbs.

B. M. W.

The B. M. W. or Bayern engine is built by the Bayerische Motoren Werke of Munich, Germany. It was used successfully by the Germans in place of the Mercedes 180-h.p. engine during the latter part of the war. In general the construction is typical of most German designs, but the engine is featured in its unusually low fuel consumption and performance at altitude which is the result of a high compression ratio and choked down carburetor setting.

The B. M. W. is a six-cylinder vertical water-cooled engine of 150 mm. (5.91 in.) bore, 180 mm. (7.09 in.) stroke, and a total displacement of 1163.34 cu. in. It develops normally 234 h.p. at 1400 r.p.m. and 254 h.p. at 1600 r.p.m. The normal brake mean effective pressure is 113.5 lbs. per sq. in. and the maximum brake mean effective pressure, which occurs at 1300 r.p.m., is 115 lbs. per sq. in. The compression ratio is 6.42 to 1.

The fuel consumption is approximately .42 lbs. per h.p-hr., and the oil consumption .042 lbs. per h.p-hr. A special design of triplex carburetor, which has a center choke of 27 mm. (1.06 in.) diameter and side chokes of 26 mm. (1.02 in.) diameter, is used. The main jet flows 196 cc. and the pilot jet 42 cc.

Lubrication is maintained by a Mercedes type plunger pump, which delivers 24 lbs. pressure. The centrifugal water

Fig. 93. Transverse Section through Cylinder of B. M. W. Engine.

Fig. 94. Transverse Section through Vertical Driveshaft of B. M. W. Engine.

pump has two outlets, one leading to the bottom and the other to the top of the end cylinders. All of the cylinder water passages are connected together. Dual ignition is supplied by two Bosch Z-H-6 magnetos. The dry weight is stated to 643.5 lbs., or 2.75 lbs. per h.p.

The cylinders are machined from steel forgings and have sheet-metal water jackets welded in place. The camshaft, which is mounted overhead, is provided with a half compression gear. There is one inlet and one exhaust valve per cylinder each with a clear diameter of 68 mm. (2.67 in.) and 30 degree seats. The inlet valve lift is 12.9 mm. (.508 in.) and the exhaust valve lift is 12.48 mm. (.491 in.). The inlet

valves open 5 degrees early and close 36 degrees late; the exhaust valves open 60 degrees early and close 20 degrees late.

The crankshaft is a six-throw seven-bearing type having plain bearings with the white metal lining a steel shell. The connecting rods are of tubular section, and the aluminum pistons are ribbed inside and provided with three rings each.

Fig. 96. Inlet Side of B. M. W. Engine.

BOLAND

The Boland Aeroplane and Motor Company of Newark, New Jersey, from 1912 to 1914, produced three eight-cylinder Vee type water-cooled engines with separately cast cylinders of vanadium grey iron. Concentric type valves were operated by single push rods and rockers.

The crankshaft was of built-up construction which facilitated the use of boltless connecting rods. The sections were joined by a disk between crankpins one and two, and likewise between three and four. A larger roller bearing was used at the center and the end bearings were plain. The normal operating speed of all Boland engines was 1400 r.p.m.

The **60-h.p.** model weighed 240 lbs., or 4 lbs. per h.p. The bore and stroke were 4 in., and the total displacement 402.08 cu. in. The mixture was supplied by a Schebler carburetor, and the ignition by either Bosch or Mea high tension magnetos.

Fig. 97. The Boland 60-h.p. Engine.

The 70-h.p. model had a 4 in. bore, 4.5 in. stroke, and a total displacement of 452.4 cu. in. The weight was said to be 255 lbs., or 3.64 lbs. per rated h.p.

The **100-h.p.** engine was said to weigh 325 lbs., or 3.25 lbs. per rated h.p. The bore was 4.5 in., the stroke 5.5 in., and the total displacement 699.76 cu. in.

BREDA

The Breda is an eight-cylinder 90 degree Vee type engine rated at 320 h.p., which is being developed in Italy.

BREESE

The Breese was a three-cylinder radial engine rated 40 h.p. at 1400 r.p.m. The bore and stroke were 4 in. and 6 in. respectively, and the total displacement was 226.19 cu. in. A Zenith carburetor furnished the mixture, and lubrication was of the force feed type. The dry weight was stated to be 163 lbs., or 4.07 lbs. per rated h.p.

BRITISH ROTARY

The British Rotary was a ten-cylinder air-cooled rotary engine built in England during 1913. The bore was 124 mm. (4.88 in.) and the stroke 140 mm. (5.52 in.), giving 103.25 cu. in. as the displacement per cylinder and a total displacement of 1032.5 cu. in. The engine was rated at 100 h.p.

BROOKE

The Brooke "Non Gyro" Motor, which was built in Chicago some years ago, had ten rotating cylinders and could be run on either five cylinders independently. The bore and stroke were 4.25 in., and the total displacement was 602.9 cu. in. This engine was rated at 85 h.p.

Two Stromberg carburetors furnished the mixture, and two-cylinder type magnetos the ignition. Lubrication was maintained by a force feed oiler. The inlet valves were located in the piston head and the exhaust valves in the cylinder head. Light springs were used to keep the valves in place when the engine was idle, but had no function during running.

An air-cooled rotary engine known as the Brooke "Multi-X" was built with six cylinders in two rows of three. The bore was 3.5 in., the stroke 4 in., and the total displacement 230.88 cu. in. This engine was rated at 24 h.p.

BROTHERHOOD

The Brotherhood was a supercharged engine, rated at 600 h.p., which was experimented with in England during the war. This engine was built to Ricardo designs by Messrs. Peter Brotherhood of Peterboro.

Fig. 98. Brott Air-cooled Engine.

BROTT

Mr. A. Brott of Denver, Colorado, built four and eight-cylinder Vee type engines during 1910 and 1911. These engines were built in both air and water-cooled forms, and operated at a normal speed of 1200 r.p m. The four-cylinder air-cooled model was rated at 35 h.p. and the water-cooled model at 45 h.p. The eight-cylinder engine was built only for air cooling and was rated at 60 h.p.

The cylinders were made of cast iron with either the water jackets or cooling fins integral. The valves were located in the cylinder head and operated by push rods. Lubrication was by splash with a pump to maintain a constant level.

Fig. 99. Brouhot 60-h.p. Engine.

BROUHOT

The Brouhot engine, which was built in France during 1909 and 1910, developed approximately 60 h.p. at 1400 r.p.m. This was a water-cooled engine having eight cylinders arranged in Vee form. The cylinder bore was 105 mm. (4.13 in.), the stroke 110 mm. (4.33 in.), and the total displacement 464 cu. in. The dry weight was stated to be 308 lbs., or approximately 5 lbs. per h.p.

Fig. 100. The Bucherer Engine.

BUCHERER

The Bucherer engine was an early German design of the two-cylinder air-cooled rotary type. The bore was 90 mm. (3.54 in.), the stroke 161 mm. (6.34 in), and the total displacement 124.8 cu. in. The compression ratio was 5.3 to 1. Fig. 100 shows this engine mounted in a testing stand. The propeller drive was by an internal gear, and the valves were lifted by arms having fulcrums in front of the cylinders and cams running in grooves at the rear.

BUCHET

The Buchet engines were early French six-cylinder designs which appeared in both vertical and radial forms.

Six-cylinder Vertical. The six-cylinder vertical engine was water-cooled. The cylinders were constructed in pairs and had overhead valves which were operated by push rods. Ignition was supplied by magnetos.

Six-cylinder Radial. The Buchet six-cylinder radial engine was air-cooled, and rated 24 h.p. at 1800 r.p.m. The bore and stroke were 80 mm. (3.15 in.), hence the displacement per cylinder was 24.54 cu. in., and the total displacement 147.24 cu. in. The weight, stated to be 110 lbs., gives 4.6 lbs. as the weight per rated h.p.

Fig. 101. Buchet Six-Cylinder Vertical Engine.

BUGATTI

The Bugatti engines were originally designed and built in France during the war by Ettoire Bugatti, a well-known automobile designer. The first engine was an eight-cylinder all-in-line type fitted with reduction gears. There was found to be no need for an engine of this form, so a sixteen-cylinder model was built with two all-in-line eights mounted upon the same crankcase. The two crankshafts were geared to a common central propeller shaft, which was made hollow to permit the firing of a French 37-mm. cannon mounted between the two sets of cylinders.

The French Government did not take up the building of these engines immediately, so Bugatti shipped both models to the United States. The tests showed up structural weaknesses, and since the engine was not considered suitable from a production point of view, it was decided to redesign and build the sixteen-cylinder model at the Duesenberg Motors Corp., Elizabeth, N. J., under the direction of Charles B. King. The new engine proved to be much better than the original French built model, so production was begun at once in the Duesenberg plant. At the signing of the Armistice, when production was stopped, forty of these engines had been tested and accepted by the Government. Further development, or the use of this engine in the air, however, has not been considered seriously.

Fig. 102. Bugatti Eight-Cylinder Vertical Engine.

Eight-Cylinder. The eight-cylinder Bugatti engine was a vertical water-cooled type of 110 mm. (4.33 in.) bore, 160 mm. (6.3 in.) stroke, and a total displacement of 742.16 cu. in. The compression ratio was 5 to 1. It was stated that the engine developed normally 210 h.p. at 1880 r.p.m. and 250 h.p. at 2160 r.p.m. The propeller speed was reduced through plain gearing at the ratio of 32 to 47.

The fuel consumption was reported to be .478 lbs. per h.p-hr., and the oil consumption 4 lbs. per hr. Either two Bugatti or two Zenith carburetors having 58 mm. chokes, 210

Fig. 103. Longitudinal Section, King-Bugatti Engine.

cc. main jets, and 200 cc. compensating jets were used. A gear pump provided pressure lubrication.

The cylinders were cast from iron in groups of four and included a frame for attaching, by means of screws, the sheet-iron or steel plates which formed the water jackets. A single overhead camshaft was made in two sections and driven at the center by a vertical shaft and bevel gears. The two inlet valves and the one exhaust valve in each cylinder were operated by separate rocker arms. The clear diameter of the inlet valve was 35 mm. (1.417 in.) and the exhaust valve 52 mm. (2.047 in.). Both valves had 10 degree seats and lifted 12 mm. (.472 in.). The exhaust valve stems were made hollow for the purpose of cooling by air circulation. The inlet valve opened at top center and closed 45 degrees late; the exhaust valve opened 45 degrees early and closed 15 degrees late.

The crankshaft was built up from two conventional four-cylinder shafts coupled together at right angles by a tapered joint at the center main bearing. Plain bearings were provided on either side of a crank throw, hence there were a total of nine main bearings. The propeller shaft was located above and to one side of the crankshaft center. By mounting the rear propeller shaft bearing on the side of the crankcase instead of forward in the usual manner, it was possible to keep the overall length to a minimum.

The connecting rods had "H" sections, and the aluminum pistons were fitted with five rings. The cooling water was circulated by a centrifugal pump, and dual ignition was provided by two H-L-8 Bosch magnetos. The dry weight was stated to be 485 lbs.

Sixteen-Cylinder. The sixteen-cylinder vertical twin Bugatti engine was formed from the cylinder blocks of the eight-cylinder model. The total displacement was 1484.29 cu. in., and the rated output 400 h.p. at 2100 r.p.m. The dry weight was stated to be approximately 1000 lbs. The approximate overall dimensions are: length 44.25 in., width 24.8 in., and height 32.28 in.

Two crankshafts, similar to those used in the eight-cylinder engine, were geared to a common propeller shaft at a ratio of 2 to 3. Four Zenith carburetors, each mounted on a manifold feeding four cylinders, were located on the outside of the

Fig. 104. Transverse Section, King-Bugatti Engine.

cylinder blocks. Dual ignition was furnished by four magnetos, two for each row of eight cylinders.

King-Bugatti. The American version of the French sixteen-cylinder Bugatti design, known as the King-Bugatti, was produced by the Duesenberg Motors Corporation under the direction of Chas. B. King. This engine was rated at 420 h.p., and stated to weigh 1248 lbs. dry, and with water in the jackets 38 lbs. more.

The principle dimensions and form of construction were the same as the original French model. A number of design improvements affecting the valves, propeller reduction gears,

water pump, oiling system, etc., were made. The ignition was changed to Splitdorf and Simms units with distributors mounted on the ends of the camshaft. Four Miller carburetors with the float chambers to the side were used. The plates for the water jackets were made of aluminum instead of sheet steel.

Fig. 105. King-Bugatti Engine.

BURGESS

An experimental sixteen-cylinder "X" type air-cooled engine, estimated to develop 500 h.p., was built in Cleveland from the designs of Mr. Roland White and Mr. Burgess of the former Burgess Company, of Marblehead, Massachusetts.

BURLAT

Among the many peculiar ideas that have been proposed for the construction of airplane engines, perhaps the most remarkable are those presented in the designs of the Burlat Brothers. Their first engine was designed in 1904 and exhibited at Paris in 1905. These engines have never been made to give satisfactory results in practice. The scheme is claimed to have been originally proposed for other purposes several years previous.

The Burlat was an air-cooled rotary engine in which the cylinders and crankshaft rotated in the same direction, the crankshaft turning twice the speed of the cylinders. The connecting rods were fixed rigidly to two opposed pistons as shown in Fig. 106. The small circle represents the path of the two crank pins located 180 degrees apart and the large circle the path of cylinder unit. Each piston traveled four times the radius of the crankshaft and completed one stroke during a single revolution of the crankshaft. Geometrically this action can be explained by the fact that any point on a circle rolling within a fixed circle of twice the diameter describes a straight line which is actually the diameter of the larger circle.

Fig. 106. Diagram of the Burlat Rotary Engine.

The crankshaft bearings were mounted in a frame that also carried the trunnion bearings of the cylinder casing. The propeller was attached to the crankshaft. As the engine operated on the four-stroke cycle it follows that the cylinders made two and the crankshaft four revolutions per cycle.

The following table gives the principle characteristics of four Burlat air-cooled rotary engines.

Rated h.p.	35	60	75	120
Number cylinders	8	8	8	16
Bore (mm.)	95	120	120	120
Bore (inches)	3.74	4.72	4.72	4.72
Stroke (mm.)	120	120	170	120
Stroke (inches)	4.72	4.72	6.69	4.72
Normal r.p.m.	950	950	950	900
Total displacement (cu. in.)	414.82	661.84	936.08	1323.68
Weight (lbs.)	187	264	308	495
Wgt. (lbs. per h.p.)	5.34	4.40	4.10	4.13

BURT

The Burt was an experimental water and air-cooled twelve-cylinder Vee type engine rated at 180 h.p. The bore was 140 mm. (5.51 in.), the stroke 94 mm. (3.70 in.), and the total displacement 1058.76 cu. in. The propeller speed was reduced .4 that of the crankshaft. The oil was circulated by a plunger pump.

CALL

The Call airplane engines were horizontally opposed types with two or four cylinders of 6 in. bore and 5.25 in. stroke. The two-cylinder engine, which had a total displacement of 296.31 cu. in., was rated at 45 h.p. and said to weigh 135 lbs. The four-cylinder engine was rated at 90 h.p. and said to weigh 225 lbs.

The cylinders were made of vanadium alloy iron, machined inside and outside, and pressed into magnalium water jackets. The cylinder barrels and valve seats were water-cooled, and air circulation was depended upon for cooling the valve cages. The cylinder head was constructed similarly to the barrels, a circular plate of iron over the combustion chamber lining the main portion of the head which was made from magnalium.

The valves were mechanically operated through push rods, and auxiliary ports for disposing of the hottest exhaust gases were provided in the cylinder near the end of the stroke.

These are said to be the first airplane engines fitted with mufflers. Tubes extending vertically downward were attached to both the exhaust valve cages and auxiliary exhaust ports.

The pistons had internal cooling ribs and were cast from the same grade of iron as the cylinders. The splash system of lubrication was employed, there being individual oilers on the tops of the cylinders to maintain the supply. A magneto furnished the ignition.

Fig. 107. The Call Four-Cylinder Engine.

CATO

Mr. J. L. Cato built a two-cylinder horizontally opposed air-cooled engine at San Francisco, California during 1910. The bore was 4 in., the stroke 5 in., and the total displacement 125.66 cu. in. The engine was rated 35 h.p. at 1500 r.p.m., and weighed 146 lbs., or 4.17 lbs. per rated h.p. The compression ratio was 4.33.

The cylinders with integral cooling fins were made of cast iron, and fitted with single inlet and exhaust valves of 1.75 in. clear diameter and 45 degree seats. The inlet valves operated automatically, the normal lift being .375 in., and the exhaust

valve lift was .3125 in. The pistons were made with flat heads from cast iron and fitted with three rings and a floating pin having brass end buttons.

The two-throw crankshaft was supported in two plain bearings and provided with a ball bearing to carry the propeller thrust. The connecting rods had "H" sections. Lubrication was by a non-circulating splash system, and a Mea high tension magneto supplied one spark plug per cylinder. The carburetor used was a Schebler Model D. The overall dimensions were as follows: length 23 in., width 48.25 in., and height 24 in.

During 1912, Mr. Cato built a four-cylinder vertical water-cooled engine rated 60 h.p. at 1400 r.p.m. The bore was 4.5 in., the stroke 5.5 in., and the total displacement 349.88 cu. in. The compression ratio was 5 to 1.

The cylinders were made from cast iron and fitted with corrugated copper water jackets. An automatically operated inlet valve was situated directly above the exhaust valve in an "L" shaped combustion chamber, and one spark plug was placed in the center of the head. The inlet valve diameter was 1.75 in., and the exhaust valve diameter 1.875 in. and its lift .375 in. The cast-iron pistons had flat heads and were fitted with four rings.

The four-throw crankshaft was supported in five plain bearings, and the connecting rods had "H" sections. The crankcase was made of aluminum and jointed along the horizontal centerline. A three-bearing camshaft was carried in one side of the crankcase and driven by a Morse silent chain.

A bronze centrifugal pump circulated the cooling water, and a gear pump was included in the constant level splash system of lubrication. The ignition was provided by a Bosch magneto, and the mixture by a Stromberg Model L (1.25 in.) carburetor. The complete weight of this engine was said to be 210 lbs., or 3.5 lbs. per rated h.p.

The Marlin-Rockwell Co. of New Haven, Connecticut, built a later two-cylinder horizontally opposed air-cooled engine designed by Mr. Cato. The bore was 5 in., the stroke 6 in., and the rated horsepower 72 at 1825 r.p.m. The compression ratio was 4.33, and the total displacement 235.62 cu. in. The weight was stated to be 134 lbs.

The cylinder barrels had integral cooling fins and were made from steel. The cast-iron heads were held down by long studs from the crankcase. Holes drilled below the lower cooling fin provided air circulation to the piston. One camshaft and two cams operated, through push rods, a single inlet and exhaust valve of 2.75 in. diameter in each cylinder.

The two-throw crankshaft was mounted on two ball-bearings, the inside race of the front bearing and of the two crankpin roller bearings being machined on the shaft. The connecting rods were of "H" section, and had the outside race of the crankpin and wrist pin roller bearings machined therein. The wrist pin in turn had an inside roller bearing race machined on it. The aluminum pistons were provided with eight webs having air circulating ports for cooling. Bronze buttons were employed for locating the wrist pin in the piston.

Fig. 108. The Cato Model C-2.

Zenith carburetors supplied the mixture, and Bosch magnetos dual ignition. Lubrication was of the dry sump principle. A dual plunger pump delivered oil to the gear case and every 7½ revolutions sent a shot of oil to the cylinders. The roller and ball bearings were lubricated by spray.

The Cato Model C-2 is a later two-cylinder air-cooled design of 5.375 in. bore, 6 in. stroke, and 272.2 cu. in. total displacement. It is estimated to develop 70 h.p. at 1800 r.p.m., and weigh 154 lbs., or 2.2 lbs. per rated h.p.

The cylinder is made from cast iron with cooling flanges integral, and supported by a flange and eight studs to the

one-piece aluminum crankcase. The valves in the cylinder head are inclined to the vertical axis, and operated by means of push rods and rockers. Each valve measures 2.75 in. outside diameter; the inlet lifting .4375 in. and the exhaust .375 in. The flat head Magnalite pistons have three rings above the piston pin. The two-throw crankshaft is carried in ball bearings, while the crankpin bearing is a plain babbitted type.

The lubrication is by a low pressure circulation system, the oil being pumped by crankcase compression. A high tension magneto supplies dual ignition, and a Miller or Zenith carburetor the mixture. The overall dimensions are as follows: length 29.75 in., width 47 in., and height 22.125 in.

CENTRUM

The Centrum was an early European six-cylinder water-cooled radial design which operated on the two-stroke cycle. The bore and stroke were 150 mm. (5.91 in.) and 140 mm (5.51 in.), respectively. The displacement per cylinder was therefore 151.15 cu. in. and the total displacement 906.9 cu. in. This engine was rated 150 h.p. at 900 r.p.m.

CHENU

The French built Chenu airplane engines closely resembled the conventional automobile engine of that time. The "L" head type cylinders were cast in pairs from iron, with the water jackets integral, and arranged vertically in line on an aluminum crankcase. The six-cylinder models employed a four-bearing crankshaft, and had two separate carburetors attached to a single inlet manifold. The pistons were made from pressed steel, and ignition was furnished by Bosch magnetos.

A four-cylinder vertical water-cooled Chenu engine, having 110 mm. (4.33 in.) bore, 130 mm. (5.12 in.) stroke, and a total displacement of 301.56 cu. in., was built in both direct and geared types. In 1913 the direct drive engine was rated 50 h.p. at 1300 r.p.m. and the following year it was rated 65 h.p. at 1800 r.p.m. The geared engine ran normally at 2300 r.p.m. and was reported to have developed 90 h.p. The weight of the direct drive engine was stated to be 254 lbs. and the propeller reduction gears 22 lbs.

A six-cylinder vertical water-cooled engine, of the same bore and stroke and 452.34 cu. in. total displacement, weighed approximately 395 lbs. This engine was also built in both direct and geared types, the weight of the reducing gears amounting to 31 lbs. In 1913 the direct drive engine was rated 80 h.p. at 1350 r.p.m. The year following it was rated at 90 h.p. and said to have developed 100 h.p. at 1600 r.p.m. The geared engine operated normally at 2300 r.p.m.

Fig. 109. Six-Cylinder 80-h.p. Chenu Engine.

A six-cylinder vertical water-cooled Chenu engine, developed for use in dirigibles, was rated 200 h.p. at 1200 r.p.m. and 250 h.p. at 1500 r.p.m. The bore was 150 mm. (5.91 in.), the stroke 200 mm. (7.87 in.), and the total displacement 1295.34 cu. in. A ten-hour supply of oil was carried in the base chamber. The dry weight was stated to be 950 lbs.

Fig. 110. The 200-h.p. Chenu Engine.

CHRISTOFFERSEN

During 1915, the Christoffersen Aircraft Company of Oakland, California, brought out a six-cylinder vertical water-cooled engine rated 120 h.p. at 1400 r.p.m. The bore was 4.75 in., the stroke 6 in., and the total displacement 637.98 cu. in.

The cylinders were cast in pairs of vanadium iron and fitted with a single water jacket of copper. The overhead camshaft, of the enclosed Mercedes type valve gear, was made in three parts. There was one inlet and one exhaust valve per cylinder, each with 2.375 in. clear diameter.

The six-throw seven-bearing crankshaft was fitted with a double-row ball bearing to take the propeller thrust. The connecting rods were of "H" section, and the aluminum pistons were fitted with two rings.

Lubrication was of the force feed type with a pressure between 40 and 80 lbs. maintained at the bearings. An oil cooler was incorporated in the oil pan. The mixture was ordinarily supplied from one duplex carburetor, and dual ignition was provided by two magnetos.

A twelve-cylinder, which was a two-fold likeness of the six-cylinder engine, is reported to have been developed. This engine was rated 240 h.p. at 1400 r.p.m.

Fig. 111. Inlet Side of Christoffersen Engine.

Fig. 112. Section and Side View of Christoffersen Engine.

CLEMENT-BAYARD

One of the first French built Clement engines, appearing in 1910, was a seven-cylinder water-cooled horizontal radial type. The bore was 100 mm. (3.94 in.), the stroke 115 mm. (4.53 in.), and the total displacement 386.61 cu. in. This engine was rated 50 h.p. and operated normally at speeds from 1100 to 1200 r.p.m.

The single-throw counterbalanced crankshaft stood vertically and drove the propeller through bevel gears having a ratio of 2 to 3. Three principal connecting rods, which were carried upon two sets of balls, one upon the inner two rings and the third upon an intermediate pair, had the four other rods attached to them. The assembly of the sleeve to which the connecting rods were attached, was made possible by the design of the removable crank pin.

The cast-steel cylinder heads had steel barrels screwed in place and welded. The water jackets, which were made from copper, were clamped in place and soldered. The valves in the cylinder head were operated through push rods and rockers by a single four-point cam rotating in the direction of the crankshaft at one-eighth speed. The valves were held to their seats by flat springs, the usual helical spring being used on

the rocker arms. Convex head pistons were made from pressed steel.

The mixture was fed into a crankcase compartment from which pipes were connected to all the cylinders. The cooling water entered the cylinder jackets on the under side. For ignition a separate distributor operated at half speed, while a high tension magneto was driven directly from the crankshaft. The weight of the engine was reported as 154 lbs., or 3.1 lbs. per rated h.p., and the overall diameter 36 in.

Two-Cylinder Opposed. Later there was also built another horizontal water-cooled engine which had two cylinders in opposed arrangement. The bore was 5.125 in., the stroke 4.375 in., and the total displacement 180.5 cu. in. This engine was rated at 30 h.p. and weighed 110 lbs. The cylinders were of steel construction, and for ignition the engine was equipped with Bosch magnetos. The overall dimensions have been given as follows: length 26 in., width 39 in., and height 19 in.

Fig. 113. Clement Two-Cylinder Engine.

Vertical Types. This firm also built four and six-cylinder vertical water cooled engines; the smaller four-cylinder model, which appeared in 1910, having a 100 mm. (3.94 in.) bore, 120 mm. (4.72 in.) stroke, and 230.2 cu. in. total displacement. This engine was rated at 29 h.p., and stated to weigh 213 lbs., or 7.35 lbs. per rated h.p.

An engine of the same size, which was built four years

later was rated 40 h.p. at 1500 r.p.m., and stated to weigh 242 lbs., or 6.05 lbs. per rated h.p.

A larger four-cylinder vertical water-cooled Clement engine was produced in 1910 with 190 mm. (7.48 in.) bore, 230 mm. (9.06 in.) stroke, and 1592.52 cu. in. total displacement. This engine was rated 118.5 h.p., and stated to weigh 1100 lbs., or 9.3 lbs. per h.p. In 1914 an engine of the same displacement and weight was rated 215 h.p. at 1200 r.p.m., or 5.12 lbs. per rated h.p.

The early six-cylinder vertical Clement engine was rated 117.5 h p., and stated to weigh 880 lbs., or 7.5 lbs. per rated h.p. The bore was 155 mm. (6.10 in.), the stroke 185 mm. (7.28 in.), and the total displacement 1276.2 cu. in.

Fig. 114. Clement-Bayard 250-h.p. Engine.

A large Clement-Bayard six-cylinder vertical water-cooled engine, shown at the Olympia show in 1914, was designed particularly for use in airships and hydro-airplanes. The bore was 155 mm. (6.10 in.), the stroke 200 mm. (7.87 in.), and the total displacement 1380 cu. in. This engine was rated 250 h.p., but developed 280 h.p. at 1400 r.p.m. The weight was reported to be 850 lbs., or 3.4 lbs. per rated h.p.

The separate steel cylinders were fitted with copper water jackets. The camshaft was located overhead and had a half compression gear for starting. It was driven by a vertical

shaft having universal joints at each end. Valve adjustments were made by a serrated washer held against similar serrations on the rocker arm at the pin about which the two were supported.

Two carburetors were attached to manifolds feeding three cylinders each. Oil was fed to the bearings under pump pressure, and ignition was provided by a magneto. The engine was equipped with a Bosch electrical starter.

Fig. 115. Clement-Bayard 300-h.p. Airship Engine.

Since the signing of the Armistice, there has been announced a Clement-Bayard airship engine rated 300 h.p. at 1200 r.p.m. This is a water-cooled vertical eight-cylinder in-line model of 165 mm. (6.5 in.) bore, 225 mm. (8.86 in.) stroke, and 2352 cu. in. total displacement.

The separate cylinders are made from steel and fitted with copper water-jackets, this being the usual form of cylinder construction used on Clement-Bayard engines. The exhaust valve is water-cooled on its interior and an additional small valve is provided for use as a decompressor in starting. The magneto has an automatic spark advance which can be controlled by hand when starting the engine.

A sixteen-cylinder water-cooled Vee type engine for airship use is now being developed. The propeller is driven direct from the crankshaft which runs normally at 900 r.p.m. The design closely resembles the eight-cylinder 300-h.p. airship engine.

CLERGET

Clerget, Blin and Cie, 37 Rue Cavé, Levallois, Paris, are among the best known French firms constructing airplane engines. During the past nine or ten years they have built various types, but more particularly air-cooled rotaries, on which their efforts were almost entirely concentrated during the period of the war. Gwynnes, Ltd., Hammersmith Iron Works, London W. control the British manufacturing rights on Clerget engines.

Vertical Types. One of the early Clerget designs was a four-cylinder vertical water-cooled engine of 110 mm. (4.33 in.) bore, 120 mm. (4.72 in.) stroke, and 278 cu. in. total displacement. At 1450 to 1500 r.p.m. the engine was rated at 50 h.p.

The cylinders were made separately from steel and had expansion bellows in the electrolytically deposited copper water jackets. The concentric valves were mechanically operated by push rods and rockers, the push rod actuating the inlet valve being inside the tubular rod which controlled the exhaust. The engine was provided with forced lubrication and magneto ignition.

A larger four-cylinder model was rated 100 h.p. at 1250 r.p.m. The bore was 140 mm. (5.51 in.), the stroke 160 mm. (6.30 in.), and the total displacement 600.88 cu. in. This engine was of the same design generally as the smaller four-cylinder model.

Vee Types. An eight-cylinder 90 degree Vee type engine, a double form of the larger four-cylinder model and closely resembling it in design, was rated 200 h.p. at 1250 r.p.m. Two carburetors and two magnetos were used, and the dry weight was stated to be 640 lbs., or 3.2 lbs. per rated h.p. The camshaft was situated in the Vee and could be moved axially for the purpose of changing the period of opening on the inlet and exhaust valves.

Rotary Types. Several air-cooled rotary types with seven, nine, and eleven cylinders have been built along the same general lines as follows:

The cylinders are machined with integral cooling fins from solid billets of steel. These are held in place through the gripping of the steel crankcase which is split vertically in

the plane of the cylinders. The nose piece of the crankcase carries the propeller hub, and the crankshaft is built up in sections. At one end of the crankshaft is attached a flowing jet bloc tube type carburetor.

Both the crankshaft and connecting rods are fitted with ball bearings. The articulated type connecting rods all have tubular sections, and the pistons are fitted with three piston rings and two obturator rings, the latter being carried in the same groove, one inside the other. There is one inlet and one exhaust valve in each cylinder operated through rockers and individual tappet rods from the cam ring, which is rotated by an eccentric with teeth, a design feature distinctively Clerget.

The oil is circulated by plunger pumps, and the ignition is furnished by high tension magnetos. The high tension current is taken to a carbon brush, suitably located on the back plate, which later conducts the current to a distributor. Distributor sectors are connected by bare wires to the spark plugs.

Type 7Y. One of the first Clerget air-cooled rotary engines had seven cylinders, and was rated 60 h.p. at 1200 r.p.m.

Fig. 116. Clerget 80-h.p. Engine.

The bore and stroke were 120 mm. (4.72 in.), and the total displacement was 578.13 cu. in. The fuel consumption was said to be .63 lbs. per h.p-hr. The weight is reported as 198 lbs., or 3.3 lbs. per rated h.p.

Type 7Z. A larger seven-cylinder rotary, commonly known as the 80-h.p. model, has an effective output of 85 h.p. at 1200 r.p.m. The compression ratio is 4 to 1. The bore and stroke are 120 mm. (4.72 in.) and 150 mm. (5.91 in.), respectively, and the total displacement 723.87 cu. in. The fuel consumption is stated to be .665 lbs. per h.p-hr., and the oil consumption .12 lbs. per h.p-hr.

The valves are timed as follows: inlet opens on top center and closes 50 degrees late; the exhaust opens 68 degrees early and closes from 0 to 5 degrees late. The weight is stated to be 216 lbs., or 2.7 lbs. per rated h.p. The approximate overall dimensions are, diameter 36.25 in. and length 32 in.

The construction of an engine of this type with an increase in the length of the stroke to 155 mm. (6.1 in.) has been reported.

110-h.p. A nine-cylinder Clerget engine, using the same cylinders as the 7Z model, had a total displacement of 930.69 cu. in., and was rated 110 h.p. at 1200 r.p.m. The compression ratio was 4 to 1. The fuel consumption was stated to be .675 lbs. per h.p-hr., and the oil consumption .168 lbs. per h.p-hr. The weight was reported as 395 lbs., or 3.6 lbs. per rated h.p.

Type 9Z. Another Clerget nine-cylinder air-cooled rotary engine, which had a 120 mm. (4.72 in.) bore, 160 mm. (6.3 in.) stroke, and a total displacement of 992.07 cu. in., developed 121 h.p. at 1200 r.p.m. and 123 h.p. at 1300 r.p.m. The compression ratio was 4.36 to 1. The fuel consumption was stated to be .79 lbs. per h.p-hr., and the oil consumption .146 lbs. per h.p-hr. The oil pressure maintained was from 20 to 25 lbs. The dry weight was reported to be 367 lbs., or 3.03 lbs. per normal horsepower.

The clear diameter of the inlet valve was 40 mm. (1.575 in.) and the lift 10 mm. (.394 in.). The clear diameter of the exhaust valve was 50 mm. (1.969 in.) and the lift 11.5 mm. (.4528 in.). The inlet valve opened 4 degrees early and closed 56 degrees late, and the exhaust opened 68 degrees early and closed 4 degrees late.

Type 9B. This engine superseded the 9Z model and was built both in France and England. This was a nine-cylinder rotary of 120 mm. (4.72 in.) bore, 160 mm. (6.3 in.) stroke, and 992.07 cu. in. total displacement. With the normal compression on ratio of 4 to 1, the engine was rated 130 h.p. at 1250 r.p.m., but gave an effective output of 135 h.p. at this speed. The maximum horsepower resulting from the use of high compression was 153.

Fig. 117. Clerget 130-h.p. Engine.

The fuel consumption was reported to be .665 lbs. per h.p-hr., and the oil consumption ranged from .096 to .168 lbs. per h.p-hr. The oil pressure was from 10 to 35 lbs. per sq. in. The weight was said to be 381 lbs.

The valves were timed in the English built models the same as in the 9Z. Both French built engines were timed as follows: the inlet valve opened at top center and closed 52 degrees late; the exhaust valve opened 64 degrees early and closed at top center.

Fig. 118. Cross Section of Clerget 130-h.p. Engine.

Type 9F. This was a French built Clerget nine-cylinder model employing a new type of cam, which together with the longer stroke and higher compression, gave more power than the 9B type. The bore was 120 mm. (4.72 in.), the stroke 170 mm. (6.69 in.), and the total displacement 1053.54 cu. in. The compression ratio was 6.3 to 1. The output was rated at 200 h.p., the actual horsepower developed being 197 at 1300 r.p.m. and 202 at 1350 r.p.m. The dangerous speed was said to be 1500 r.p.m. The weight was reported as 374 lbs., or 1.87 lbs. per rated h.p., and the overall diameter was 40.2 in.

Type 9BF. An English built nine-cylinder Clerget had a 120 mm. (4.72 in.) bore, 172 mm. (6.77 in.) stroke, and a total displacement of 1066.14 cu. in. This engine was rated at 140 h.p. and weighed 381 lbs., or 2.72 lbs. per rated h.p. At a normal speed of 1250 r.p.m. the effective horsepower with a 5.1 to 1 compression ratio was 146, and with a 5.3 to 1 compression ratio it was 153. The fuel consumption was stated to be .656 lbs. per h.p-hr., and the oil consumption .156 lbs. per h.p-hr.

Type 9J. A small nine-cylinder air-cooled rotary model recently built in England is rated 100 h.p. at 1300 r.p.m. The bore is 105 mm. (4.13 in.), the stroke 140 mm. (5.51 in.), and the total displacement 664.29 cu. in. The fuel consumption is reported to be .63 lbs. per h.p-hr., and the oil consumption .156 lbs. per h.p-hr. The engine is said to weigh 250 lbs., or 2.5 lbs. per rated h.p. The compression ratio is 5.1 to 1.

The cylinder construction varied from usual Clerget practice. The steel cylinder head was made separately from the barrel which was cast from aluminum with cooling fins integral and enclosed a steel liner.

Type 11EB. An eleven-cylinder air-cooled rotary engine, which has been built both in France and England, has a 120 mm. (4.72 in.) bore, 190 mm. (7.48 in.) stroke, and a total displacement of 1439.68 cu. in. The compression ratio is 5 to 1. This engine is normally rated at 200 h.p., but develops from 220 to 230 h.p. at 1300 r.p.m. The consumption of fuel is said to be .63 lbs. per effective h.p-hr., and the consumption of oil .132 lbs. per effective h.p-hr. The weight is reported to be 500 lbs., or 2.5 lbs. per rated h.p. The overall diameter is 43.25 in.

Fig. 119. Clerget Eleven-Cylinder Rotary Engine.

Type 11G. A French built model, similar to the Type 11 EB engine except for a 5.7 to 1 compression ratio, was rated at 250 h.p. This engine was said to develop 256 h.p. at 1300 and 265 h.p. at 1400 r.p.m. The dangerous speed was considered to be 1500 r.p.m. The weight was stated to be 497 lbs., or 1.99 lbs. per rated h.p. and the overall diameter 42.9 in. This engine superseded an eleven-cylinder model of 120 mm. bore and 180 mm. stroke.

Eighteen-Cylinder. An experimental eighteen-cylinder air-cooled rotary type was rated at 300 h.p. and said to develop 350 h.p. at 1350 r.p.m. The bore was 120 mm. (4.72 in.), the stroke 170 mm. (6.69 in.), and the total displacement 2107.08 cu. in. This engine was said to weigh 660 lbs., and measure 40.5 in. overall diameter.

Type 11A. An experimental variable compression Clerget rotary engine having a rated output of 200 h.p has been built.

Fig. 120. Clerget "X" Type Engine.

Type X. One of the latest Clerget developments is a sixteen-cylinder water-cooled "X" type engine rated at 400 h.p. The bore and stroke are 130 mm. (5.12 in.), and the total displacement is 1685.44 cu. in. The rated output is developed normally at 1550 r.p.m. and 420 h.p. at 1600 r.p.m. The fuel consumption is stated to be .567 lbs. per h.p-hr., and the oil consumption .06 lbs. per h.p-hr. The dry weight is reported to be 770 lbs., or 1.92 lbs. per rated h.p. The approximate overall dimensions are as follows: length 52 in., width 39 in., and height 39 in.

Twin. A two-cylinder air-cooled horizontally opposed engine, recently marketed for use in small single-seater sport planes, is rated at 10 h.p., but said to develop 16 h.p. The bore

Fig. 121. The Clerget Two-Cylinder Air-Cooled Engine.

is 85 mm. (3.25 in.), the stroke 100 mm. (3.94 in.), and the total displacement 69.46 cu. in. The engine is reported to weigh 48.5 lbs.

The cylinders with cooling fins are machined from steel forgings. The valves are situated in the cylinder head and operated by means of push rods and rockers. Roller bearings are used for the crankshaft and the big end of the connecting rods, and the pistons are cast from aluminum.

CLEVELAND

The Cleveland engines, designed by Walter C. Willard, were water-cooled barrel types planned so that many of the same parts could be used on a number of sizes ranging from 100 to 600 h.p. The Model 4 herein described was rated at 150 h.p. This was a six-cylinder engine of 5 in. bore, 6 in. stroke, and 706.86 cu. in. total displacement.

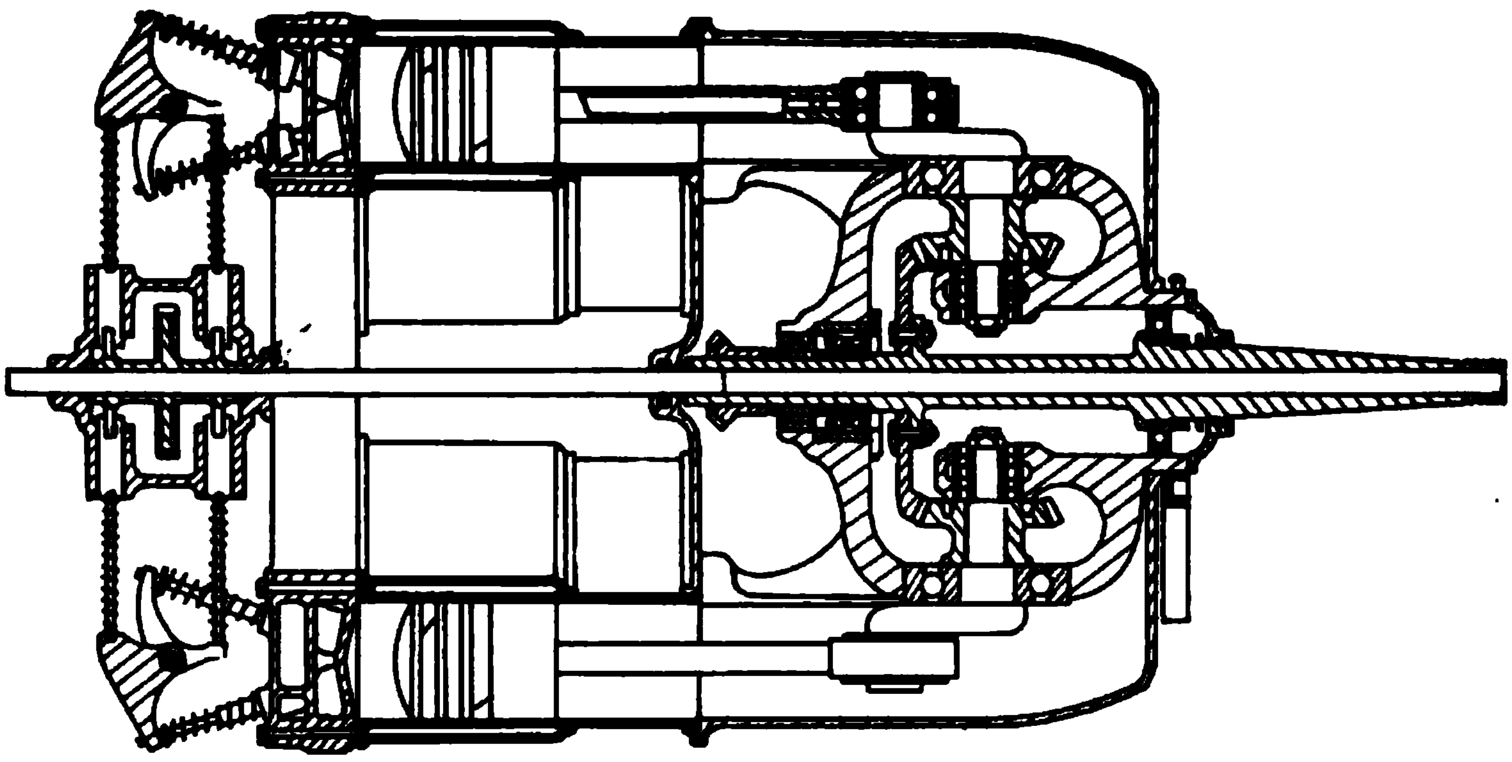


Fig. 122. The Cleveland Aero Engine.

The propeller speed was reduced to one-half that of the crankshaft, thereby permitting the cams to be mounted upon the propeller shaft. There were six single-throw crankshafts having bevel gears meshing with a large "bull gear." The engine was lubricated by feeding oil on the "bull gear" where it was thrown about so as to properly lubricate all the other parts. Ball bearings were used throughout.

A combined cylinder head and intake manifold was cast from aluminum, while each cylinder barrel was of steel tubing with the spark plug bosses and water jackets welded in place.

There were two inlet and two exhaust valves per cylinder seating in phosphor bronze rings. Each pair of valves were operated through a single bell crank and push rod from a central cam which served for all cylinders. The pistons were made from aluminum and fitted with three rings. Ignition could be provided by two magnetos, two battery units or one of each.

COLOMBO

The Colombo engines were built in Italy from the designs of an engineer by that name. The study of these engines was begun in 1915 and the early types gave such excellent practical results that they were built in large numbers in the shops of the Eduardo Bianchi Company and the Officine Meccaniche Nazionali De Vecchi of Milan. The D type Colombo engines were quite extensively used by the Italian Air Service.

Model C. The Model C Colombo engine was a six-cylinder vertical water-cooled type rated at 160 h.p.

Fig. 123. The Model D Colombo Engine.

Model D. The Model D Colombo engine was a six-cylinder vertical water-cooled type of 120 mm. (4.72 in.) bore, 160 mm. (6.3 in.)stroke, and 661.14 cu. in. total displacement. This engine was rated at 110 h.p. and reported to develop normally 115 h.p. at 1350 r.p.m. The fuel consumption has been stated as .528 lbs. per h.p-hr., and the oil consumption .048 lbs. per h.p-hr. Duplex Zenith carburetors supplied the

mixture, and pressure lubrication was maintained by a gear pump.

The cylinders were made from cast iron and fitted with a sheet-steel water jacket. The single inlet and exhaust valves in each cylinder were operated by an overhead camshaft. The six-throw crankshaft had four main bearings, and the pistons were made of aluminum. Dual ignition was supplied by two six-cylinder magnetos. The dry weight has been given as 474 lbs., or 4.3 lbs. per rated h.p.

Model E. The Model E Colombo engine was a six-cylinder vertical water-cooled type rated at 150 h.p.

COMBI

The Combi is a six-cylinder vertical water-cooled engine rated at 150 h.p. which is reported to be under development in Italy.

COSMOS

The Cosmos air-cooled radial engines are now produced by the Bristol Airplane Company. The manufacture of these engines was taken over in 1920 after the failure of the Cosmos Engineering Co., which was a reorganization of the former well-known firm, Brazil-Straker Co., Ltd., Fishponds, Bristol England.

Before the war, Brazil-Straker and Co., Ltd., built the 15-h.p. Straker-Squire car, having for eight years concentrated on the one chassis which gained for them a world-wide reputation. In 1915 the Admiralty requested this company to undertake airplane engine construction and after some experimental work on Curtiss engines they took up the manufacture of Rolls-Royce engines and parts. With the exception of the experimental engines built by the Rolls-Royce Company, Brazil-Straker manufactured all of the 75-h.p. Rolls-Royce "Hawk" models, as well as the Series I 190-h.p. twelve-cylinder "Falcons." As a matter of fact, this was the only firm to build and test Rolls-Royce engines other than the Messrs. Rolls-Royce themselves. They also are known to have manufactured completely the 80-h.p. W. S. Renault and a number of parts for the Rolls-Royce "Eagle" engines.

Early in 1917 the firm was requested by the Air Board to design engines meeting special requirements and after con-

sideration it was decided to concentrate on the radial air-cooled types. The design of the Cosmos "Mercury" was started in July, 1917, and the first engine finished early in 1918. The results were then sufficiently gratifying to warrant undertaking other air-cooled radial designs. Although the Cosmos engines are still in the development state, they are of particular interest, since they mark one of the first serious attempts to use large air-cooled cylinders in the fixed radial forms.

Fig. 125. Propeller End of Cosmos "Jupiter" I.

"Jupiter," Series I. This is a nine-cylinder direct drive air-cooled radial engine of 5.75 in. bore, 7.5 in. stroke, and 1752.75 cu. in. total displacement. The engine is rated 400 h.p. at 1650 r.p.m. and 450 h.p. at 1800 r.p.m. The compression ratio is 5 to 1. The fuel consumption is stated to be .557 lbs. per h.p-hr., and the oil consumption between .06 and .07 lbs. per h.p-hr. Three H-C-8 Claudel carburetors with 44 mm. chokes and 720 c.c. jets furnish the mixture. Lubrication is of the dry sump type, gear pumps being used to maintain oil pressure on the bearings and to scavenge the sump.

The cylinders are machined from a solid billet of steel with circumferential cooling fins and a closed cylinder head upon which is bolted an aluminum cap containing the valve ports and valve guide bushings. It was expected that the

Fig. 126. Magneto End of Cosmos "Jupiter" I.

aluminum would assist in dissipating the heat from the steel cylinder head or at any rate more evenly distribute it and thereby tend to prevent valve warpage. On the steel cylinder head are seated two inlet and two exhaust valves, the clear diameter of the inlet being 1.875 in. and the exhaust 1.6875 in.

The aluminum crankcase is split vertically in the plane of the cylinders, the rear section containing three spirals which provide three-cylinder distribution. The single-throw one-piece crankshaft is mounted with roller bearings, while the crankpin bearing is plain. The master connecting rod, which is split at the big end and held together by four bolts, has four linked rods hinged on either side of the split. All of the rods are made with an "H" section. The aluminum pistons are fitted with three top rings, and dual ignition is furnished

by two Thompson-Bennett magnetos. The dry weight is stated to be approximately 700 lbs. The overall outside diameter is 54.5 in. and the length inside the propeller hub 32 in.

Fig. 127. Longitudinal Section of Cosmos "Jupiter" II.

"Jupiter"—Series II. This engine has epicyclic propeller gears of .656 reduction, giving the propeller a normal speed of 1300 r.p.m. It is rated 450 h.p at 1850 r p.m. and 500 h.p. at 2000 r.p m. The Series II engine is reported to weigh approximatley 800 lbs., and measures 39.625 in. long inside the propeller hub.

Except for the addition of the gear compartment and construction of the connecting rods, the design corresponds closely to the Jupiter Series I. The big end of the master connecting rod has an outside bearing upon which is hinged a

separate counterweight that guides itself in the main counterbalance and serves to relieve the high centrifugal loads on the crankpin bearing.

"Jupiter," Series III. This engine corresponds with Series II, but has the normal propeller speed reduced to 660 r.p.m.

"Hercules." This is an air-cooled radial engine with eighteen cylinders arranged in two rows of nine. The bore is 6.25 in., stroke 7.5 in., and the total displacement 4141.8 cu. in. The engine is rated 1000 h.p. at 1750 r.p.m., and is fitted with an epicyclic reduction gear to give the propeller a normal speed of 1150 r.p.m. The weight is stated to be 1400 lbs.

Fig. 128. The Cosmos "Lucifer" Engine.

The construction of the cylinders is similar to the Jupiter models. There are four valves per cylinder, and the spiral induction system of manifolding is employed. The two-throw crankshaft with counterweights is made in one piece and mounted on roller bearings. Dual ignition is furnished by a special Delco unit, and an electric starter having an epicyclic reduction gear is employed.

"Lucifer." The smallest Cosmos engine is a three-cylinder air-cooled radial type of 5.75 in. bore, 6.25 in. stroke, and 486.87 cu. in. total displacement. This engine is rated 100 h.p. at 1600 r.p.m., and the propeller is driven direct from the crankshaft. The fuel consumption is said to be .557 lbs. per h.p-hr., and the oil consumption .025 lbs. per h.p-hr. Lubrication is on the dry sump principle with pressure and scavenging pumps of the gear type. The dry weight is reported to be 300 lbs.

The cylinder construction is similar to the Jupiter model. The crankshaft is made from a one-piece solid forging, and the connecting rods have "H" sections. A modified slipper type aluminum piston is fitted with three top rings and one oil scraper ring at the bottom. Dual ignition is furnished by generators and distributors, and a hand crank can be arranged in the cockpit for starting.

"Mercury." The original Cosmos design was a two-row fourteen-cylinder air-cooled radial type. The bore is 4.375 in., the stroke 5.8125 in., and the total displacement 1223.32 cu. in. The compression ratio is 5 to 1. This engine is rated 315 h.p. at 1800 r.p.m. and 347 h.p. at 2000 r.p.m. The fuel consumption is stated to be .544 lbs. per h.p-hr., and the oil consumption .09 lbs. per h.p-hr. Two Ware duplex carburetors feed the gas mixture into a circular induction manifold, and with the dry sump system of lubrication gear pumps are used to circulate the oil.

There are two inlet and two exhaust valves situated vertically in each cylinder of the usual Cosmos type of construction. The two-throw crankshaft is fitted with roller bearings throughout. Individual plain type connecting rods are mounted with separate roller bearings side by side upon the crankpin. Ignition is provided by two M-L magnetos and a fourteen-cylinder Remy distributor. The dry weight is re-

Fig. 129. The Cosmos "Mercury" Engine.

ported to be 587 lbs., and the overall diameter measures 41.625 in.

CURTISS

The first successful airplane engines marketed in America were those designed and built at Hammondsport, N. Y., by the pioneer aviator and inventor, Glenn H. Curtiss, who previous to turning his attention to aviation, had built a number of engines for other purposes. The numerous records made by Curtiss planes and engines are a matter of history. The early development of airplane engines in America, however, can be duly represented by the steady advancement in the types built by Curtiss.

In order to fulfill large contracts with the British government early in the war, several plants were taken over for that purpose in Buffalo and elsewhere. The Curtiss Aeroplane and Motor Corporation then built the OX and V engines in both Buffalo and Hammondsport factories.

During 1917 and 1918 the K-12 and K-6 engines were designed under the direction of Chas. B. Kirkham, who was then chief engineer. The Curtiss Engineering Corporation was organized about this time for the purpose of doing the engineering and experimental work for the Curtiss Aeroplane and Motor Corporation and others. A plant was built at Garden City, L. I., and the balance of the organization was moved there when the production of planes and engines was stopped by the Government at the signing of the Armistice.

C-1. The first Curtiss engine was a single-cylinder air-cooled model which developed 3 h.p. at 1800 r.p.m. The bore and stroke were 3.25 in., and the displacement was 26.96 cu. in. This engine was said to weigh 40 lbs. Roller bearings were mounted on the crankshaft, and battery ignition and a splash system of lubrication were employed.

A-2. A two-cylinder air-cooled engine of 3.25 in. bore, 3.625 in. stroke, and 60.14 cu. in. total displacement was said to develop 7 h.p. at 1500 r.p.m. Battery ignition and splash lubrication were used. The engine was stated to weigh 50 lbs., and measure approximately as follows: height 17 in., width 3.125 in., and length of case 10 in.

A-4. A four-cylinder air-cooled model of 3.25 in. bore and stroke, and 107.84 cu. in. total displacement, was rated 15 h.p. at 1800 r.p.m. and said to weigh 90 lbs. A sight feed oiler was used in connection with a splash system of lubrication, and the ignition current was supplied by a battery. The chrome-steel crankshaft was mounted in plain bearings of Parson's White Brass and McAdamite Metal. The approximate overall dimensions were as follows: length 20 in., height 15 in., and width 7 in.

B-4. A design with 3.625 in. bore, but otherwise corresponding to the A-4 model, was rated 20 h.p. at 1800 r.p.m. The total displacement was 134.16 cu. in., and the engine was said to weigh 100 lbs., or 5 lbs. per h.p.

C-4. The larger of the four-cylinder air-cooled models was rated 25 h.p. at 1800 r.p.m. The bore was 3.625 in., the stroke 4 in., and the total displacement 165.12 cu. in. Ignition was furnished by a magneto. The engine was said to weigh 110 lbs., or 4.4 lbs. per rated h.p. The overall dimensions were as follows: length 20 in., height 18 in., and width 7 in.

Fig. 130. The Curtiss Model C-4 Engine.

A-8. An air-cooled eight-cylinder 90 degree Vee type, of the same bore and stroke as the A-4 Model, was rated 30 h.p. at 1800 r.p.m. The total displacement was 215.68 cu. in., and the engine weighed 140 lbs., or 4.66 lbs. per rated h.p.

B-8. An air-cooled model B, of 3.625 in. bore and 3.25 in. stroke, was also built with eight cylinders in 90 degree Vee arrangement. The total displacement was 268.32 cu. in. This engine was rated 40 h.p. at 1800 r.p.m. and weighed 150 lbs., or 3.75 lbs. per rated h.p. The Model B-8 was the first Curtiss engine to sustain a heavier-than-air machine in flight and it is also said to have been the first to lift a helicopter.

E-4. The first water-cooled Curtiss engine was a four-cylinder vertical type rated 50 h.p. at 1500 r.p.m. The bore and stroke were 5 in., and the total displacement was 392.70 cu. in. The weight was stated to be 250 lbs., or 5 lbs. per rated h.p.

The cylinders were made from cast iron and fitted with copper water jackets. The inlet valve was located on the side and the exhaust valve in the cylinder head. Battery ignition and a splash feed system of lubrication were employed.

E-8. A double form of the E-4 model, having eight identical cylinders in 90 degree Vee arrangement, was rated 100 h.p. at 1500 r.p.m. The total displacement was 785.40 cu. in., and the weight was stated to be 350 lbs., or 3.5 lbs. per rated h.p.

H and K. A four-cylinder vertical water-cooled engine, known as Model H or Model K, was rated 40 h.p. at 1500 r.p.m. The bore was 4 in., the stroke 5 in., and the total displacement 251.32 cu. in. The weight was stated to be 175 lbs., or 4.38 lbs. per rated h.p. The overall dimensions were as follows: length 20 in., height 30.5 in., and width of bed 12 in.

One Schebler carburetor furnished the mixture, and a Bosch magneto the ignition. A combination splash and pressure feed system of lubrication with pumps of the gear type was employed. The cylinders were made from cast iron and had sheet-metal water jackets brazed in place. The inlet and exhaust valves, inclined in the cylinder head, were operated by a single push rod and rocker arm.

Fig. 131. The Curtiss Model H and I Engine.

S. A six-cylinder water-cooled engine, having the same bore and stroke as the H and K models, was rated 60 h.p. at 1600 r.p.m. and reported as capable of developing 60 h.p. at 1100 r.p.m. and 70 h.p. at 1325 r.p.m. The total displacement was 376.98 cu. in., and the weight was said to have been 245 lbs., or 4.08 lbs. per rated h.p. The approximate overall dimensions were as follows: length 31.125 in., height 30.5 in., and width of bed 12 in.

L. An eight-cylinder Vee type water-cooled engine of similar construction, but with 4 in. bore and 5 in. stroke, was rated 80 h.p. at 1500 r.p.m. The total displacement was 502.64

Fig. 132. The Curtiss Model S Engine.

cu. in., and the weight was reported as 285 lbs., or 3.56 lbs. per rated h.p. The approximate overall dimensions were as follows: length 50 in., height 27 in., and width 30 in.

O. An improved design of the Model L engine, known as Model O, was rated 75 h.p. at 1100 r.p.m.

OX. The Model O design was in turn refined and later known as the Model OX. This engine was rated 90 h.p. at 1200 r.p.m. Several types, such as the OX-2 and OX-5, were built with various kinds of equipment in order to facilitate special installations.

The OX and OXX Curtiss models have probably been used more extensively than any other American-built airplane engine. They were installed in the Curtiss JN airplanes which were standard for training in the U. S. A. and Canadian armies during the war. The reliability for which these engines are well known is the result of several years development, the design itself being practically the same as that originally laid down in 1914.

The cylinders are cast individually from grey iron and have monel metal jackets brazed in place. Single inlet and exhaust valves seating directly in the iron cylinder head are inclined to the vertical axis and operated by means of push and pull rods and rocker arms. Eight double acting cams are integral with the camshaft that is situated in the Vee. The aluminum camshaft bearings are of the split type bolted together and held in place by lock screws.

The crankshaft is a four-throw five-bearing type. The connecting rods of opposite cylinders are arranged side-by-side on the crankpin and have "H" sections. The pistons are made from aluminum alloy and fitted with two rings.

Ignition is provided by a single spark eight-cylinder magneto, and a duplex Zenith carburetor furnishes the mixture.

Fig. 134. Timing End, Curtiss OX-5 Engine.

Fig. 135. Plan View, Curtiss OX-5 Engine.

Fig. 136. Bottom View, Curtiss OX-5 Engine.

Fig. 137. Side and Propeller End View of the Curtiss V2 Engine.

From 40 to 60 lbs. oil pressure is maintained by a gear pump which forces the oil from the base chamber to the rear end of the hollow camshaft from where it is led to the timing gears and all the bearings. The fuel consumption is said to be .60 lbs. per h.p-hr., and the oil consumption .03 lbs. per h.p-hr. The dry weight is reported to be 390 lbs., or 4.33 lbs. per rated h.p. The approximate overall dimensions are as follows: length 56.75 in., height 36.75 in., and width 29.75 in.

OXX. Except for the larger bore, this engine is practically the same as the OX models. The bore and stroke are 4.25 in. and 5 in., respectively, and the total displacement 567.44 cu. in. The rated output is 100 h.p. at 1400 r.p.m., and the weight 401 lbs.

V. The first eight-cylinder water-cooled Model V engine of 5 in. bore, 7 in. stroke, and 1099.56 cu. in. total displacement was rated 160 h.p. at 1100 r.p.m.

VX. Except for a few minor changes, an identical model known as the VX, was rated 180 h.p. at 1400 r.p.m.

V2. A more refined model, known as the V2, was rated 200 h.p. at 1400 r.p.m. This engine was built in several types (V2-3 to V2-10 inclusive) with slight differences to accommodate installation as in the case of the OX models.

The staggered cylinders were made individually from steel forgings, machined all over, and fitted with monel metal water jackets welded in place. Single inlet and exhaust valves of 2.5 in. clear diameter seated directly on the flat cylinder head. The inlet valve spring was of the usual coil type, while the exhaust valve spring was of the cantilever torsion type. Each valve was operated by a separate push rod and rocker arm from a camshaft mounted in the Vee.

The four-throw crankshaft was mounted in five plain bearings. The side-by-side connecting rods were of "H" section and supported an oil tube for delivering oil to the wrist pin bearing. The aluminum pistons were ribbed inside and fitted with two rings.

Dual ignition was supplied by two eight-cylinder magnetos, and two Zenith carburetors, located on either side the engine, each fed four cylinders. The oil was carried in the base chamber and delivered to the bearings under approximately 60 lbs. normal pressure by a gear pump.

Fig. 138. Side and Timing End View of the Curtiss V2 Engine.

Fig. 139. Bottom View, Curtiss V2 Engine.

Fig. 140. Plan View, Curtiss V2 Engine.

Fig. 141. Propeller End, Curtiss V2 Engine.

The fuel consumption was .54 lbs. per h.p-hr., and the oil consumption .03 lbs. per h.p-hr. The dry weight was reported to be 690 lbs., or 3.45 lbs. per rated h.p. The approximate overall dimensions were as follows: length 68 in., height 34 in., and width 37 in.

V-4. A Vee type engine using twelve of the V2 cylinders and therefore having a total displacement of 1649.34 cu. in. was rated 300 h.p. at 1400 r.p.m. and 350 h.p. at 1600 r.p.m. The weight was stated to be 1086 lbs. A hydro-plane boat with a V-4 engine for its power plant at one time held the world's speed record of 66 miles per hr.

V-3. The Curtis V-3 engine was an eight-cylinder 90 degree Vee type water-cooled engine rated 160 h.p. at 1400 r.p.m. The bore was 5 in., the stroke 7 in., and the total displacement 1099.56 cu. in. The cylinders were of aluminum construction with detachable cylinder heads in which four valves were fitted.

Fig. 142. Timing End, Curtiss V2 Engine.

The V-3 engine was designed by Chas. M. Manly to replace the original VX type. Several of these were built and sold to the Russian government, but were never delivered, as the ship carrying them was sunk on the way across.

An airplane, known as the "America" and equipped with a V-3 engine, was being prepared for a trans-atlantic flight in 1914, just prior to the outbreak of the war, through the financial assistance of John Wanamaker.

K-12. The Curtiss K-12 engine was designed and built during 1917 and 1918. This followed a thorough study of the type including the construction and test of an experimental twelve-cylinder 4 x 5 engine then known as Model AB. The K-12 engine was particularly adaptable to high speed battle planes on account of its low head resistance and low weight per h.p., but was never thoroughly developed, as the Govern-

Fig. 143. The Curtiss V-3 Engine.

ment during the emergency had decided to concentrate on the production of Liberty 12's. A Curtiss "Wasp" triplane, designed around this engine by Mr. Kirkham and flown by Roland Rolfs, at one time held the world's speed record and to date holds the World's altitude record for engines not equipped with a supercharger.

The K-12 is a twelve-cylinder 60 degree Vee type water-cooled engine of 4.5 in. bore, 6 in. stroke, and 1145.09 cu. in. total displacement. The normal compression ratio is 5.63 to 1. The output is rated at 375 h p., although 397 h.p. is developed at a normal speed of 2250 r.p.m. The normal brake mean effective pressure is approximately 122 lbs. per sq. in. and the maximum which occurs around 1700 r.p.m. is 129 lbs. per sq. in.

The propeller shaft is mounted on plain bearings and driven at a ratio of .6 through gears having staggered herring bone teeth. The dry weight of the complete engine is stated to be 678.5 lbs., or 1.70 lbs. per b.h.p., and the water content weighs 38.25 lbs. The length from the inside of the propeller hub to the end of the hand starting magneto crank is approxi-

Fig. 144. End and Side Views of Curtiss K-12 Engine.

mately 60 in. The overall height is 40.125 in., and the width 27.875 in.

A cylinder assembly consists of a detachable aluminum head into which are screwed six cylinders having combustion chambers and barrels machined from steel forgings. The jackets around the barrel are aluminum and form a part of the crankcase. A flange is provided at the top of the crankcase water jacket wall for bolting on the detachable head which is cored out for water passages around the head and valve ports. At the lower end provision is made for a cork packing ring between the crankcase and each cylinder barrel for the purpose of making a water-tight joint above the crank compartment.

Standing vertically in each cylinder are two inlet and two exhaust valves of 1.625 in. clear diameter, .406 in. lift, and 45 degree seats. The inlet valve opens on top center and closes 38 degrees late; the exhaust valve opens 48 degrees early and closes on top center. Each pair of valves are operated from an overhead camshaft through a T which is guided in the head to relieve the valve stems of side thrust and provided with screw adjustments at the ends for taking up clearance on each valve stem independently.

The exhaust camshaft is driven from the end by a driveshaft and bevel gears, the gear being bolted to a flange on the camshaft through a series of holes which give a vernier adjustment. The inlet camshaft is kept in correct angular and linear position as it is driven from the exhaust camshaft by two gears of the herringbone type on either side of center. The camshafts are supported in six aluminum double bearings that are bolted to the head and the whole is enclosed by an oil-tight cover.

The six-throw crankshaft is supported in five plain bearings, one being just ahead of the propeller drive gear, and is arranged for counterbalances, although these are generally omitted. The connecting rods have "H" sections and are of the articulated type. The linked rod is forked at the crankpin end. The aluminum pistons are ribbed underneath the head and fitted with three rings.

The fuel consumption is said to be .499 lbs. per h.p-hr., and the oil consumption .053 lbs. per h.p-hr. A Ball and Ball

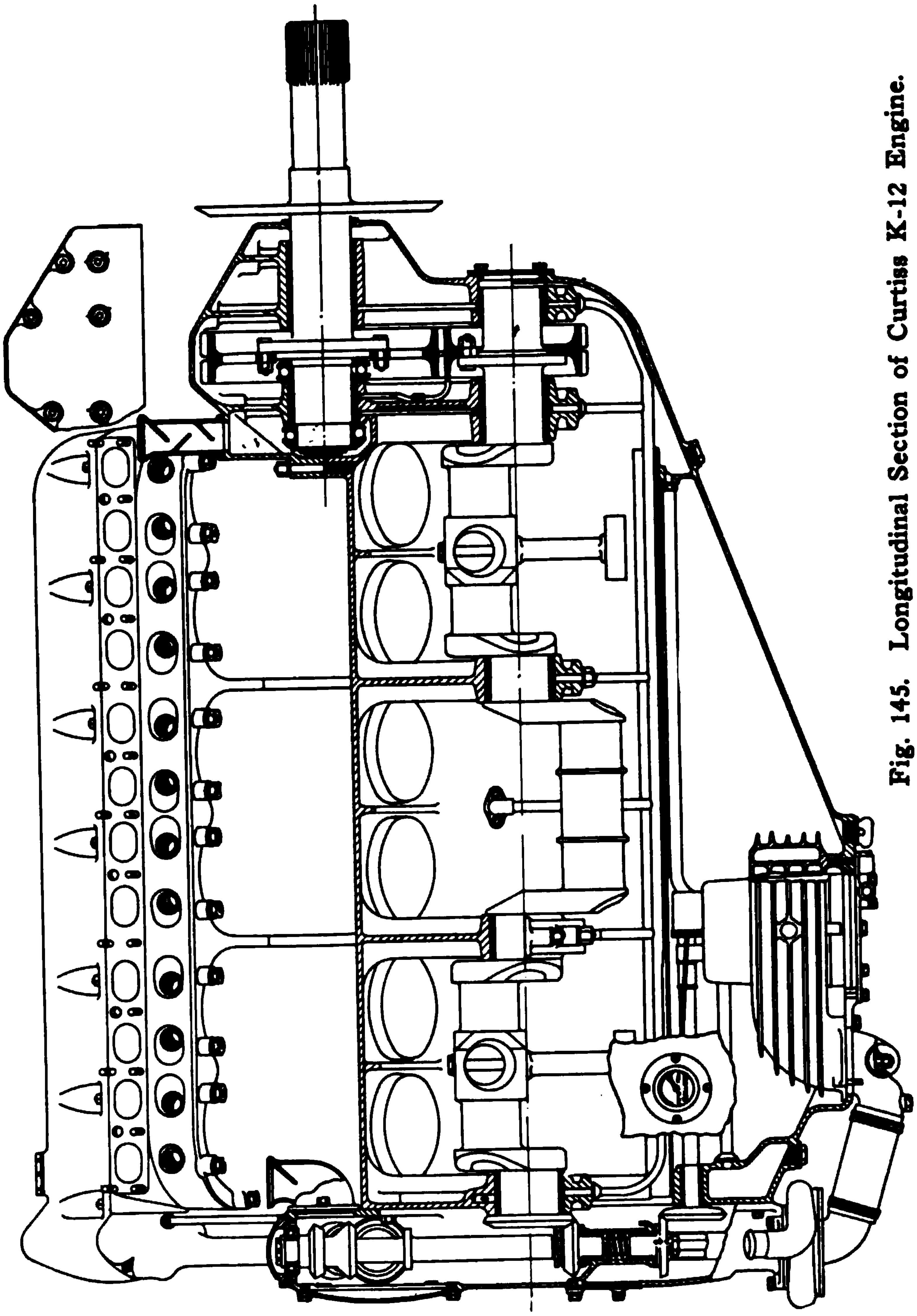


Fig. 145. Longitudinal Section of Curtiss K-12 Engine.

Fig. 146. Transverse Section of Curtiss K-12 Engine.

duplex carburetor having 1.375 in. chokes and 210 mm. jets, furnishes the mixture. Lubricating oil of one-half castor is recommended, a normal oil pressure of 80 lbs. being maintained at the bearings by a gear pump. The engine is of the dry sump type with oil carried in the base chamber. Dual ignition is provided by two Berling D-66 magnetos, one for each bank of six cylinders.

K-6. Following the K-12 was a six-cylinder vertical direct-drive engine using the same cylinder block and the same crankshaft dimensions. The total displacement is 572.54 cu. in., and the engine is rated 150 h.p. at 1700 r.p.m.

The fuel consumption is reported to be .52 lbs. per h.p-hr., and the oil consumption .03 lbs. per h p-hr. The compression

Fig. 147. The Curtiss C-12 and C-6 Engines.

ratio is 4.91 to 1. The weight is stated to be 417 lbs., and the water content 16 lbs. The overall dimensions are as follows: length 63 in., height 39.25 in. and width 22.125 in.

The design of the K-12 engine has been closely followed and as many of the K-12 parts as possible used in the construction. The camshaft driveshaft stands vertically and drives the exhaust camshaft, which is to one side of center, by virtue of skew bevel gears. The crankshaft has a total of five plain main bearings, one of these being just outside the annular ball bearing provided to carry the propeller thrust.

C-12. The Curtiss C-12 engine is a redesigned K-12 model incorporating the following changes. The packing gland at the lower extremity of the cylinder barrel is omitted by bolting the aluminum cylinder jacket to the crankcase instead of casting it integral. Without changing cylinder center distances three intermediate main bearings are added by cutting down the width of the bearings and the crank throws. Obviously no improvement could be effected thereby. The spark plugs were located diametrically opposite instead of both inside the Vee on the intake side, a position which apparently had given satisfactory results.

The C-12 engine is rated at 400 h.p., but develops 427 h.p. at 2250 r.p.m. The normal brake mean effective pressure is approximately 131 lbs. per sq. in. The fuel consumption is reported to be .503 lbs. per h.p-hr., and the oil consumption .083 lbs. per h.p-hr. The dry weight is said to be 705 lbs., or 1.649 lbs. per normal h.p.

C-6. Similarly the C-6 is a redesigned model K-6 engine. This engine develops 161 h.p. at 1750 r.p.m., corresponding to 127 lbs. per sq. in. normal b.m.e.p. The fuel consumption is reported to be .50 lbs. h.p-hr., and the oil consumption .016 lbs. per h.p-hr. The engine is stated to weigh dry 448 lbs., or 2.79 lbs. per h.p.

CD-12. The latest Curtiss development is a C-12 engine with direct driven propeller. At a normal speed of 1800 r. p.m. the engine is rated 325 h.p. The omission of the reduction gears effects a saving of approximately 25 lbs. weight, and 11 in. overall length.

DAMBLANC

The Damblanc eleven-cylinder variable compression rotary engine was built in France during 1918. The bore is 126 mm. (4.96 in.), the stroke 150 mm. (5.91 in.), and the total displacement 1256.09 cu. in. The effective horsepower is stated to be 240, the useful horsepower 220, and the fuel consumption .573 lbs. per useful h.p-hr. The normal compression ratio is 4.8 to 1 and the maximum compression ratio 7 to 1, the variation being accomplished by changing the length of the stroke. An eccentric bushing on the crankpin is turned through gears by a shaft extending through the hollow crankshaft. The single-throw crankshaft is made in two major parts and mounted on ball bearings.

Fig. 148. The Damblanc Variable Compression Engine.

Steel cylinders with integral cooling fins are fitted with liners and held in place by threads and lock nuts. The single inlet and exhaust valves of each cylinder are operated through push rods and rocker arms. The connecting rods are of the articulated type, and the pistons are fitted with three rings. The bushing for the piston pin is locked in the rod. The ignition is supplied by two magnetos. The dry weight is reported to be 441 lbs., and the outside diameter 40.16 in.

Fig. 149. The Daniel Rotary Engine.

DANIEL

The Daniel engine was a seven-cylinder air-cooled rotary type, designed and built by Paul Daniel of the Daniel Engine Company of Bound Brook, New Jersey.

DARRACQ

The Darracq horizontal and vertical type water-cooled engines made their first appearance in France about 1909. The smaller of these, a two-cylinder horizontally opposed type, had a 130 mm. (5.12 in.) bore, 120 mm. (4.72 in.) stroke, and 194.24 cu. in. total displacement. This engine was rated 24 h.p. at 1500 r.p.m., and reported to weigh 121 lbs., or 5 lbs. per rated h.p.

The cylinders were machined from a solid billet of steel and had copper water jackets hard soldered in place. In ad-

dition to the valves in the cylinder head, which were operated by means of push rods and rocker arms, holes in the cylinder wall serving as auxiliary exhaust ports were provided. Ignition was supplied by a magneto, and a pump sprayed oil into the crankcase for lubrication. No flywheel was used.

A four-cylinder horizontally opposed water-cooled engine of the same bore and stroke, and therefore 388.48 cu. in. total displacement, was rated 48 h.p. at 1500 r.p.m. The weight was reported to have been 242 lbs., or 5 lbs. per rated h.p.

Fig. 150. The Darracq Two-Cylinder Engine.

Vertical Types. A Darracq four-cylinder vertical water-cooled engine of 120 mm. (4.72 in.) bore, 140 mm. (5.51 in) stroke, and 385.64 cu. in. total displacement, was rated 43 h.p. at 1500 r.p.m. It was reported to weigh 374 lbs., or 8.7 lbs. per rated h.p.

A larger four-cylinder vertical water-cooled engine was rated 84 h.p. at 1200 r.p.m. and reported to have weighed 550 lbs., or 6.55 lbs. per rated h.p. This engine had 170 mm. (6.69 in.) bore, 140 mm. (5.51 in.) stroke, and a total displacement of 774.72 cu. in.

DAY

A five-cylinder air-cooled engine rated at 25 h.p. was used by Charles Day in a machine of his own design which he entered in the Los Angeles meet of 1910.

DE DIETRICH

The De Dietrich four-cylinder vertical water-cooled engine was one of the early French designs. The valves were located in the cylinder head and operated through push rods and rockers. Ignition was furnished by a magneto.

Fig. 151. De Dietrich Four-Cylinder Engine.

DE DION

The De Dion-Bouton Company of France built an eight-cylinder air-cooled engine about 1915, a water-cooled engine of the same type about two years later, and during the war experimented with a sixteen-cylinder "X" type.

80-h.p. The first air-cooled engine had the eight cylinders arranged in 90 degree Vee form, and was rated 80 h.p. at 1700 r.p.m. The bore was 100 mm. (3.94 in.), the stroke 120 mm. (4.72 in.), and the total displacement 460.4 cu. in. The weight has been reported as 465 lbs., or 5.8 lbs. per rated h.p. The propeller rotated at half engine speed and drove the camshaft which was located in the Vee. A forced draft system of cooling consisted of a fan, driven from the end of the crankshaft, which forced air around the cylinders through an aluminum casing fitted over the Vee.

The fuel consumption was said to be .50 lbs. per h.p-hr. The sump carried a sufficient capacity of oil for 7 hrs. running at full speed. Ball bearings were used at both ends of the crankshaft, while the three intermediate bearings were

plain. The connecting rods were of the forked design. Individual "L" head cylinders were tied down by long bolts extending to a bridge piece over the head. The valves were in pockets toward the inside of the Vee, the inlet valve being operated directly by tappets and the exhaust valve just above it by means of push rods and rockers.

Fig. 152. The De Dion Air-Cooled Engine.

150-h.p. The eight cylinder Vee type water-cooled engine was rated 150 h.p. at 1600 r.p.m. The bore was 125 mm. (4.92 in.), the stroke 150 mm. (5.91 in), and the total displacement 898.88 cu. in. The weight was reported as 968 lbs., or 6.45 lbs. per rated h.p.

800-h.p. The experimental sixteen-cylinder "X" type engine, composed of four banks of four cylinders each, was rated 800 h.p. at 1400 r.p.m. The bore was 170 mm. (6.69 in.), the stroke 190 mm. (7.48 in.), and the total displacement 4206.88 cu. in. This engine was reported to weigh approximately 1900 lbs. There were two inlet and two exhaust valves per cylinder.

DEMONT

Messrs. Demont of Puteaux, France, have constructed several rotary engines, the first of which appeared as early as 1896. An interesting Demont engine, exhibited at the Paris Aero Show of 1913, was a six-cylinder double-acting air-cooled rotary model rated 300 h.p. at 2000 r.p.m. The low weight power ratio of .73 lbs. per h.p. was claimed. The bore was 175 mm. (6.89 in.), the stroke 80 mm. (3.15 in.), and the total displacement 704.7 cu. in. The overall diameter was approximately 30 in.

Fig. 153. The Demont Double-Acting Rotary Engine.

The crankshaft was fixed and the crankcase and cylinders rotated about it upon ball bearings, an external ball bearing being provided at the propeller end to relieve the crankshaft of any bending load due to overhanging weight. The mixture was introduced through the hollow crankshaft to the rear compartment which connected all cylinders. The exhaust gases were disposed of in front.

Since the engine was double acting, there had to be an inlet and exhaust valve at both upper and lower ends of the cylinder. The valves were placed parallel to the crank axis and operated through a linkage system from the twelve cams of the sleeve mounted on the crankshaft in the nose piece. The cams were driven at half engine speed by an epicyclic gear train.

The working piston and the trunks on either side of it were fitted with rings. Internal cooling action was derived by the circulation of air over the inner piston walls. This was assisted by the centrifugal action of the rotary motion and the baffle plate in the working piston which caused the air to impinge on the hottest surfaces.

The connecting rods were made hollow and the crankpin ends were forked, each of different width, and strung upon a bushing supported on the crankpin by two ball bearings. This arrangement kept all six cylinders in the same plane. In this engine six impulses occurred at equal intervals during each revolution. A spark plug fitted in each valve pocket gave dual ignititon, the single high-tension two-spark magneto being driven at three times engine speed.

DETROIT AERO

The Detroit Aero Engines were designed and built by Mr. Fred Weinberg of Detroit, Michigan, during 1910 and 1911. One thousand or more of these engines were sold to amateur aviators throughout this country during that period.

This engine was a two-cylinder air-cooled horizontally opposed type rated from 25 to 30 h.p. at 1500 r.p.m. The bore was 5.5 in., the stroke 5 in., and the total displacement 237.48 cu. in. The valves were located in the cylinder head and operated through push rods and rockers. A magneto furnished the ignition.

D'HENIAN

The D'Henian seven-cylinder air-cooled 50-h.p. rotary engine exhibited at the Paris Aero Show of 1913 was quite similar to the 10-12 h.p. model shown in 1912. The design was unusual in that the cylinders and crankcase were made in one piece of cast-iron and the cooling fins on the cylinder head radiated from the center.

Fig. 154. The Detroit Aero Engine.

The valve mechanism was quite similar to that used on the Clerget rotary engines. Two eccentric plates, one for the inlet and the other for the exhaust, were mounted with ball bearings upon the crankshaft and in the periphery had toothed recesses into which the push rods fell for actuating the valves.

Oil was mixed with the air entering the cylinders for the purpose of lubricating the cylinder and piston. The induction mixture entered the crank compartment through the hollow crankshaft and from there it was distributed by pipes to each cylinder. The crankshaft was fitted with ball bearings throughout.

DODGE

The Dodge Tool Company of Grinnell, Iowa, built a six-cylinder air-cooled radial engine during 1918, known as the "Victory." The bore was 5 in., the stroke 6 in., and the total displacement 706.86 cu. in. The engine was rated at 125 h.p. and weighed 394 lbs.

Fig. 155. "Victory" Six-Cylinder Radial Engine.

The steel cylinders were held in place by clamping rings. Two exhaust valves were located forward and one inlet to the rear in a vertical position in the cylinder head. Plain bearings were used throughout on the two-throw crankshaft. The two connecting rod assemblies were of the articulated type, each having one master rod with two linked rods attached thereto. Dual ignition was furnished by a Bosch two-spark magneto.

DORMAN

Among the engines manufactured by Dorman & Company of Stafford, England, was an eight-cylinder 90-degree Vee type of 4 in. bore, 4.75 in. stroke, and 477.52 cu. in. total displacement. This engine was rated 80 h.p. at 1300 r.p.m. and was said to weigh 375 lbs., and with flywheel 450 lbs.

The Dorman engine was water-cooled on the cylinder barrels only, the cast-iron cylinders having jackets of spun copper secured by steel bands. Both inlet and exhaust valves employed flat seats, had a clear diameter of 2.375 in., and a lift of .3125 in. The valves were carried in cages and operated by a tappet, push rod, and rocker from plus and minus cams on a camshaft mounted in the Vee. Auxiliary exhaust ports were uncovered by the piston at the lower end of the stroke.

Fig. 156. The Dorman Eight-Cylinder Engine.

The four-throw five-bearing crankshaft was fitted with a light flywheel of 14 in. diameter. The connecting rods were of the straddle type, the center rod for the cylinder of one bank having bearings on either side for the two slender rods of the cylinder on the other bank The pistons were made from cast iron and fitted with three top rings.

DOUSELER

The Douseler engine was a four-cylinder water-cooled vertical engine used by Douseler in a Farman type machine entered in the Los Angeles meet of 1910. This engine was rated at 40 h.p., and equipped with Bosch magneto ignition.

DUESENBERG

The former Duesenberg Motors Corporation of Elizabeth, N. J., was originated in January, 1917, by Mr. Fred Duesenberg, one of America's well known constructors of internal combustion engines. The building of the various marine, automobile, and airplane engines bearing the Duesenberg name originated in a small shop in Rockford, Iowa.

Model A-44. The first Duesenberg airplane engine was a four-cylinder vertical water-cooled type rated 70 h.p. at 1500 r.p.m. The bore was 4.375 in., the stroke 6 in., and the total displacement, 360.79 cu. in. This engine was reported to weigh 365 lbs. The valves were set in the cylinder head horizontally, a construction which is common to most Duesenberg engines.

125-h.p. A larger four-cylinder vertical water-cooled engine of 4.75 in. bore, 7 in. stroke, and 496.2 cu. in. in total displacement, was rated 125 h.p. at 2100 r.p.m. The actual output at this speed was over 140 h.p. The engine was built in both direct and geared types, for the latter a plain type gear reduction of 51 to 33 ratio was used, hence the propeller had a normal speed of 1210 r.p.m. The direct drive engine delivered 100 h.p. at 1400 r.p.m., and weighed 436 lbs. The geared model weighed 509 lbs.

Fig. 157. The Duesenberg 125-h.p. Engine.

The cylinders were cast en bloc from semi-steel, and at the ends and sides aluminum plates attached by screws served as water jacket covers. The inlet and exhaust valves were opposedly arranged in a horizontal position, the inlet valve seating in a cage which when removed provided an opening for the removal of the exhaust valve that seated directly in the cylinder. The two inlet and two exhaust valves in each cylinder had a clear diameter of 1.72 in. The valves were operated by long rocker arms from a camshaft on either

side of the crankcase. The rocker arms were enclosed by an oil-tight cover.

The crankshaft was a four-throw three-bearing type. The connecting rods were made with a tubular section and a four-bolt cap, and the aluminum pistons used one three-piece ring. Dual ignition was provided by a Bosch magneto, and lubrication by a gear pump maintaining approximately 25 lbs. pressure.

Model V-12. A twelve-cylinder Vee type engine, rated 300 h.p. at 1400 r.p.m., had a 4.875 in. bore, 7 in. stroke, and a total displacement of 1567.86 cu. in. The total dry weight, including electric starter and generator, was reported to be 1040 lbs.

The cylinders were cast in pairs from iron and employed aluminum plates for water jackets. The inlet and exhaust valves set side by side at right angles to the cylinder axis and were operated from the camshaft in the Vee by long rocker arms. A continuous inlet manifold situated over the Vee was arranged for either one or two carburetors.

The crankshaft was a six-throw four-bearing type. The cylinders of one bank were not directly opposite the corresponding ones of the other bank, as side-by-side connecting rods were used. The rods had tubular sections, slightly

Fig. 158. The Duesenberg Twelve-Cylinder 300-h.p. Engine.

tapered, and employed four-bolt caps. The aluminum pistons were each fitted with one three-piece ring.

A double centrifugal pump was arranged to circulate water to each bank of cylinders independently. Two twelve-cylinder magnetos furnished dual ignition, and provision was made for an electric starter geared 25 to 1 and an electric generator, chain driven at 1.5 times crank speed.

Model H. A sixteen-cylinder 45 degree Vee type water-cooled engine rated 800 h.p. at 1800 r.p.m. was designed and built during the war. The bore was 6 in., the stroke 7.5 in., and the total displacement 3392.8 cu. in. This engine was also built with both direct and geared propeller drives. The direct drive model was reported to weigh 1390 lbs. and the geared

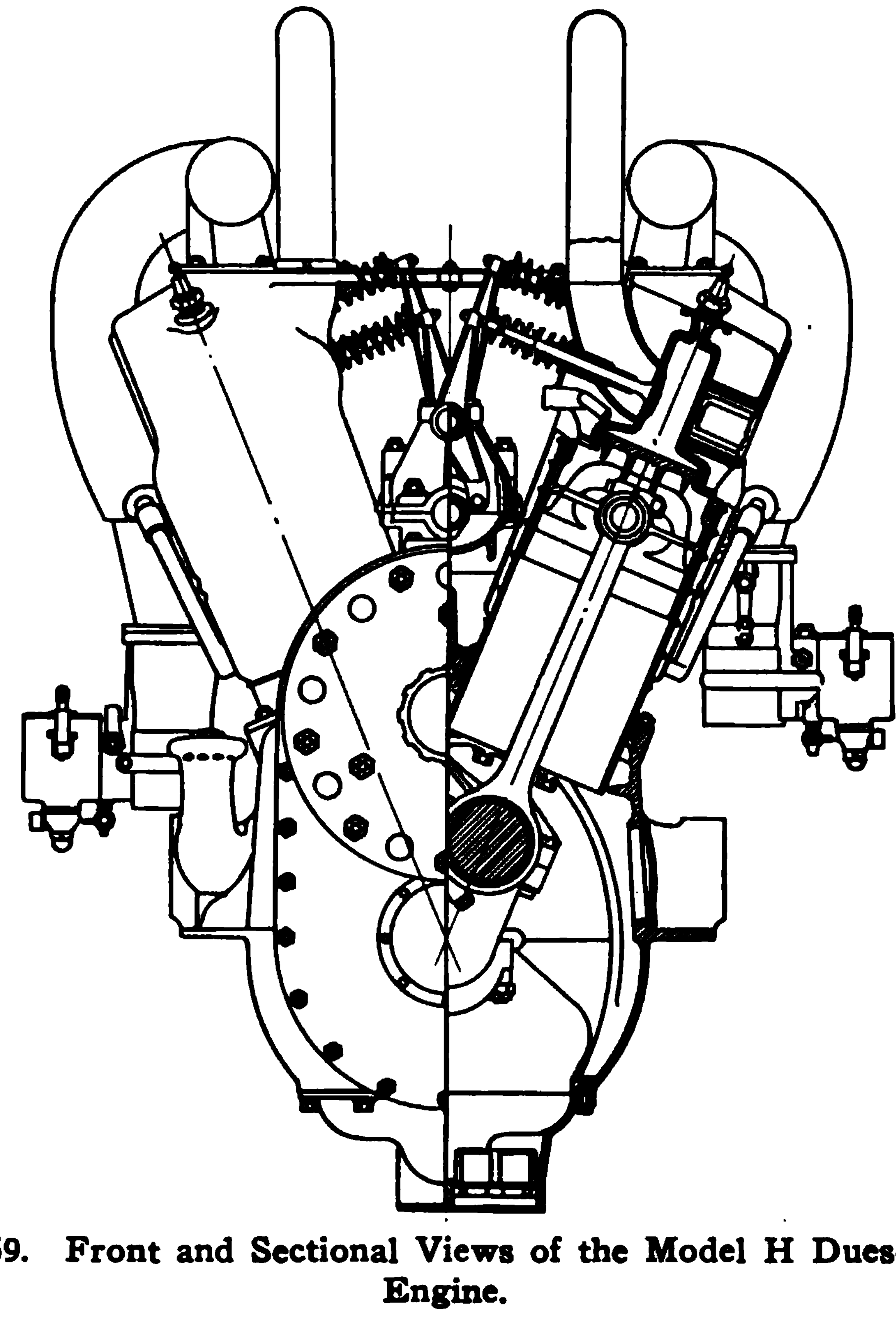


Fig. 159. Front and Sectional Views of the Model H Duesenberg Engine.

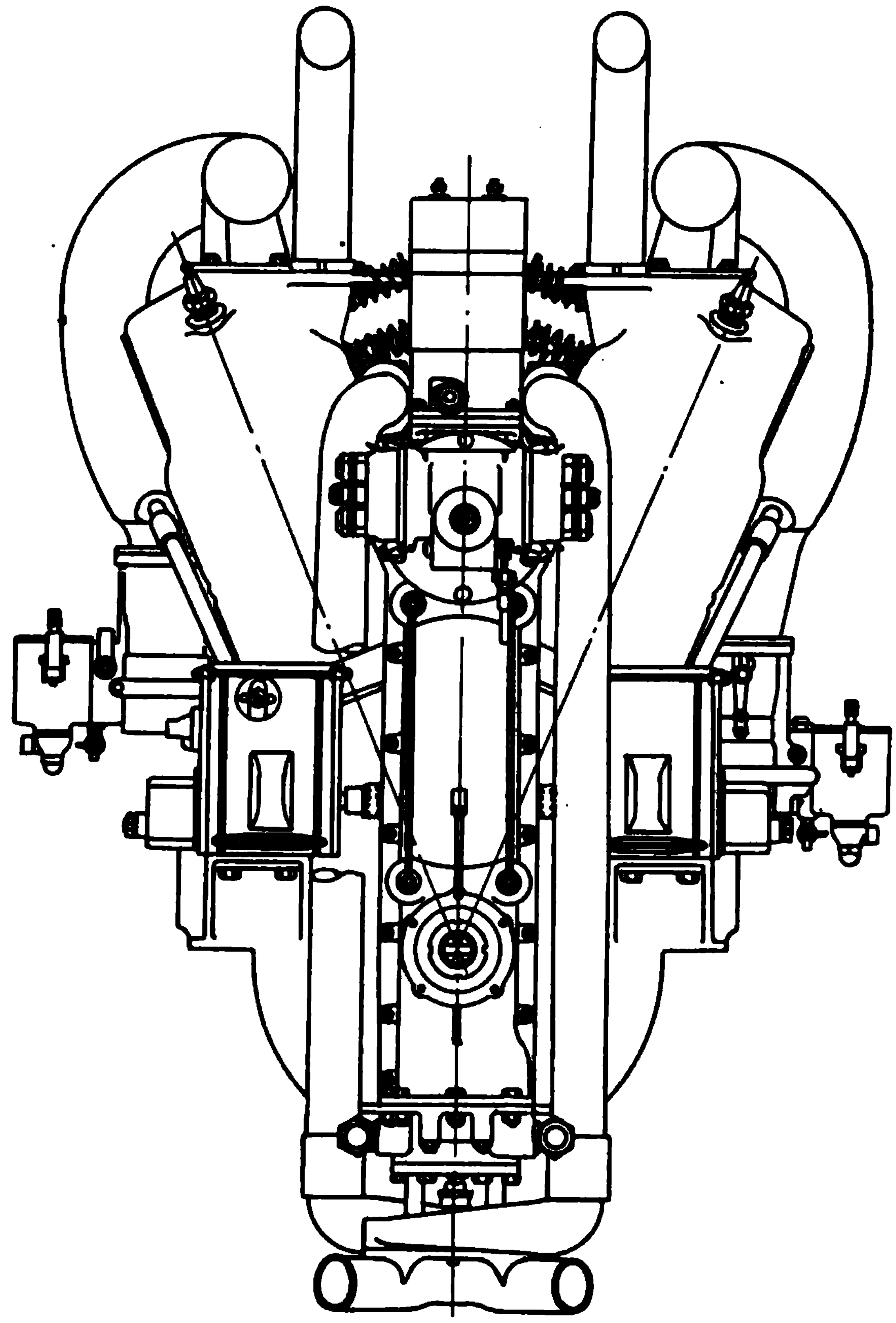


Fig. 160. Rear View of the Model H Duesenberg Engine.

model 1575 lbs. The reducing gears were of the plain spur type having a ratio of 25 to 33.

The cylinders were made individually with semi-steel heads having screwed in and welded steel barrels and welded on sheet-steel water jackets. The usual Duesenberg valve mechanism was used, but with shorter rocker arms as the single camshaft was mounted relatively higher in the Vee than on former models. Both the inlet and exhaust valves were toward the inside of the Vee and could be removed after unscrewing the plugs on the opposite side of the cylinder. Both valves had 30 degree seats. The single inlet valve had a clear diameter of 2.75 in. and was lifted .5625 in. The two exhaust valves each had a clear diameter of 2 in. and were lifted .5 in.

The crankshaft had eight throws, the four of one end being at right angles to the other four, and was mounted in four plain bearings and one ball bearing. The connecting rods were of the forked type and had tubular sections. The aluminum pistons were ribbed inside and each fitted with one three-piece ring.

Four Miller carburetors, located at the outside, furnished the mixture. The lubricating system consisted of a high and low pressure line from a unit triple gear pressure and scavenging pump, mounted in the oil pan. The high pressure line fed the crankshaft and connecting rod bearings, thence through a regulating valve to the low pressure line for the cylinders, camshaft and rocker arms. The cooling water was circulated by a centrifugal pump with double outlets, located underneath at the rear. Provision was made for both battery and magneto ignition. The approximate overall dimensions were as follows: length 88.75 in., width 32 in., and height 38.875 in.

DUFAUX

A most radical departure from conventional types was the five-cylinder tandem double-acting engine designed by Dufaux in France. This engine was the equivalent to an ordinary twenty-cylinder operating on the four-stroke cycle.

The cylinders were water-cooled, and the hollow connecting rods and pistons air-cooled. The valves were actuated by push rods, and each cylinder was fired by two spark plugs. The crankshaft was located above the cylinders, which stood in a vertical position, hence the engine had the advantage of a low center of gravity. The ordinary crankcase was completely omitted, the distribution of oil to the moving parts being made by oil feed pipes.

DUTHIEL-CHALMERS

The Duthiel-Chalmers engines were early French designs, in which the cylinders were all arranged horizontally. Except for the first 20-h.p. air-cooled two-cylinder model used in Santos-Dumont's Demoiselle, all of the later engines were water-cooled.

A two-cylinder Duthiel-Chalmers horizontal engine, rated

Fig. 161. The Duthiel-Chalmers Air-Cooled Engine.

24 h.p. at 1200 r.p.m., had a 128 mm. (5 04 in.) bore, 130 mm. (5.12 in.) stroke, and a total displacement of 204.28 cu. in. This engine was said to weigh 132 lbs., or 5.5 lbs. per rated h.p.

Cylindrical sleeve valves in the cylinder head were operated mechanically. The cylinders were held by long studs passing through clamps over the cylinder head. The water outlet and the spark plugs were located on top of the cylinder and the water inlet underneath. The crankshaft was fitted with a wire spoked flywheel, and the pistons were lubricated by special oil feeds run to the cylinder.

Another two-cylinder horizontally opposed engine, rated 37.5 h.p. at 1000 r.p.m., was built with an unusually long stroke. The bore was 110 mm. (4.33 in.), the stroke 300 mm. (11.81 in.), and the total displacement 349.4 cu. in. The dry weight was stated to be 200 lbs., or 5.9 lbs. per rated h.p.

A three-cylinder horizontal Duthiel-Chalmers engine, of the same bore and stroke and consequently a total displacement of 524.1 cu. in., was rated 56 5 h.p. at 1000 r.p.m. This engine was stated to weigh 396 lbs., or 7 lbs. per rated h.p.

A four-cylinder horizontal type was also built with the same bore and stroke. This engine had a total displacement of 698.8 cu. in. and was rated 75 h.p. at 1000 r.p.m. The dry weight is reported to have been 528 lbs., or 7 lbs. per rated h.p.

Another four-cylinder horizontal type, of approximately

the same displacement and rated at 100 h.p., was built with 160 mm. (6.3 in.) bore and 140 mm. (5.51 in.) stroke. The dry weight was said to be 638 lbs., or 6.38 lbs. per rated h.p.

The Duthiel-Chalmers engine rated 97 h.p. at 1000 r.p.m. had four horizontally arranged cylinders of 125 mm. (4.92 in.) bore and 300 mm. (11.81 in.) stroke. The total displacement was 898.04 cu. in., and the dry weight was stated to be 792 lbs., or 8.2 lbs. per rated h.p.

A Duthiel-Chalmers six-cylinder horizontal engine of 128 mm. (5.04 in.) bore, 130 mm. (5.12 in.) stroke, and 612.84 cu. in. total displacement, was rated 72.5 h.p. at 1200 r.p.m. The dry weight was reported to be 385 lbs., or 5.3 lbs. per rated h.p.

A series of Duthiel-Chalmers horizontal engines of two, four, and six cylinders and rated at 20, 40 and 60 h.p., respectively, were built with 125 mm. (4.92 in.) bore and 120 mm. (4.72 in.) stroke. The 20-h.p. engine, of 179.52 cu. in. total displacement, was said to weigh 165 lbs., or 8.25 lbs. per rated h.p. The four-cylinder 40-h.p. model had 359.04 cu. in. total displacement and weighed 264 lbs., or 6.6 lbs. per rated h.p. The six-cylinder engine of 538.56 cu. in. total displacement weighed 374 lbs., or 6.23 lbs. per rated h.p.

An interesting feature of these engines was the two spark plugs located in a valve. Either of the spark plugs could be removed while the engine was running by turning the internal tapered plug.

EASTON

The Easton eight-cylinder Vee type water-cooled engines were built during 1910. The smaller model had a 95 mm. (3.74 in.) bore, 101 mm. (3.98 in.) stroke, and a total displacement of 349.76 cu. in. This engine was rated at 50 h.p. and stated to weigh 275 lbs., or 5.5 lbs. per rated h.p.

The larger model had a 114 mm. (4.48 in.) bore and stroke, and a total displacement of 564.96 cu. in. This engine was rated at 75 h.p. and stated to weigh 300 lbs., of 4 lbs. per rated h.p.

EDELWEISS

The Edelweiss air-cooled radial engines, exhibited at the Paris show in 1913, embodied an unusual form of construc-

tion. The pistons were fixed by being attached to a large aluminum outer casing, while the cylinders were reciprocated by long external connecting rods attached to the crankpins. Two rods were used for each cylinder and the bolts which tied them together just below the piston gained somewhat for lateral rigidity. The six-cylinder engine had a three-throw crankshaft, the two end throws being at 180 degrees to the center, and the ten-cylinder engine used a five-throw shaft.

Fig **_ine.**

The cylinders were machined from steel with cooling fins and wrist pin upon the outer surfaces. The cast-iron pistons had three rings and received the valves and spark plugs. The valves were operated by push rods and rockers. The crankshaft was supported in ball bearings fitted into the spiders at each end, the arms of the rear spider acting as inlet gas conduits.

One Zenith carburetor supplied the gas mixture, and a magneto, mounted in a recess of the outer casing and driven by worm gear from the crankshaft, supplied the ignition. The oil pump, which was located in the reservoir at the bottom of the casing, had separate leads to each piston. The pump drive and timing gears were enclosed in the compartment just ahead of the inlet manifold.

The six-cylinder model was rated 75 h.p. at 1350 r.p.m., the bore being 115 mm. (4.53 in.), the stroke 120 mm. (4.72 in.), and the total displacement 456.42 cu. in. This engine was reported to weigh 276 lbs., or 3.68 lbs. per rated h.p.

A ten-cylinder model of the same bore and stroke had a total displacement of 760.72 cu. in. This engine was rated 125 h.p. at 1350 r.p.m and reported to weigh 353 lbs., or 2.82 lbs. per rated h.p.

Fig. 163. Rear View of Edelweiss Radial Engine.

E. J. C.

The E. J. C. engine was a six-cylinder air-cooled double-rotary type of 100 mm. (3.94 in.) bore and stroke. Two propellers were used, one supported to the crankcase and turning normally at 800 r.p.m. and the other attached to the crankshaft and turning at 1200 r.p.m. in the opposite direction. This gave a relative speed of 2000 r.p.m. at which the engine was rated 60 h.p, The weight was stated to be 185 lbs., or 3.08 lbs. per rated h p.

The position of the cam plate and high tension distributor was controlled by planetary gearing at each end. Plain type connecting rods were arranged side-by-side in threes on

each of the two crankpins. Both valves were located in the cylinder head and controlled from the cam ring by push rods and rockers. A pipe to the inlet valve of each cylinder directed the mixture from the crank compartment which was supplied by a carburetor mounted on the end of the hollow crankshaft.

A ten-cylinder 100-h.p. engine of the same type is reported to have been built.

Fig. 164. The E. J. C. Double-Rotary Engine.

ELBRIDGE

In 1908, the Elbridge Engine Company of Rochester, N. Y., placed on the market two-cycle vertical type marine engines which interested amateur aviators by reason of their dependability and light weight per horsepower. A majority of the so-called successful amateur flights during the period of 1909-1911 were made with an Elbridge engine supplying the power.

Among the first engines sold to amateur aviators was Type A, a water-cooled two-cylinder engine rated at 6/10 h.p. and weighing 88 lbs. The bore was 3.75 in., the stroke 3.5 in., and the total displacement 77.32 cu. in.

Type C was a three-cylinder water-cooled engine rated at 18/30 h.p. This engine weighed 235 lbs. The bore was 4.625 in., the stroke 4.5 in., and the total displacement 226.8 cu. in.

A four-cylinder air-cooled experimental model, sold to

Fig. 165. The Elbridge Three-Cylinder "Featherweight" Engine.

Dr. Greene in 1909, had a 3.5 in. bore and stroke, and a total displacement of 134.68 cu. in.

The "Featherweight" types were placed on the market in the spring of 1910 and the three, four, and six-cylinder models became very popular for aviation. The bore and stroke were 4.625 in. and 4.5 in., respectively. The cylinders were cast from iron, and the crankcase from aluminum. Bosch magnetos were fitted for ignition, Schebler carburetors furnished the mixture, and a splash system of lubrication was employed.

The three-cylinder model, having a total displacement of 226.8 cu. in., was rated 30/45 h.p. at 1400 r.p.m. and weighed 150 lbs. The overall dimensions were as follows: length 32 in., width 12.5 in., and height 20.25 in.

Fig. 166. The Elbridge Six-Cylinder "Featherweight" Engine.

The four-cylinder model was rated 40/60 h.p. at 1400 r.p.m. The total displacement was 302.4 cu. in., and the reported weight 200 lbs. The overall dimensions were as follows: length 38 in., width 12.5 in. and height 20.25 in.

The six-cylinder "Featherweight" model was rated at 60/90 h.p. and weighed 250 lbs. The total displacement was 453.6 cu. in. The overall length was 50 in., the width and height being the same as the three and four-cylinder models.

Fig. 167. The Elbridge Aero Special.

A modified four-cylinder "Featherweight," brought out during the next year, was known as the Elbridge Aero Special. The rated output was 50/60 h.p. and the weight (minus ignition) 150 lbs. This engine was more efficient at higher speeds than the "Featherweight" types, being capable of pulling maximum loads up to 2000 r.p.m.

ELLEHAMMER

The Ellehammer rotary engine was used in the Ellehammer (Danish) biplane, which was the first to make a free flight in Europe. This machine and engine were built in 1905 and flown in 1906. The first flight in Germany was made by this machine, in June, 1908, the distance being 47 meters.

EMERSON

The Emerson was a six-cylinder engine rated at 100 h.p. The weight was said to be 300 lbs., or 3 lbs. per rated h.p.

ENDICOTT

The J. L. Endicott Airplane Company, of Medford, L. I., designed and built a three-cylinder two-cycle 60-h.p. engine for use in a biplane brought out by that company in 1910.

E. N. V.

The French and British built E. N. V. (EnVee) engines were all eight-cylinder water-cooled Vee types. The first model, which was produced in 1909, had an 85 mm. (3.35 in.) bore, 90 mm. (3.54 in.) stroke, and a total displacement of 249.6 cu. in. This engine was rated 39 h.p. at 1700 r.p.m. and reported to weigh 150 lbs., or 3.8 lbs. per rated h.p.

A larger model produced about the same time was rated 62 h.p at 1550 r.p.m. The bore was 105 mm. (4.13 in.), the stroke 110 mm. (4.33 in.), and the total displacement 464 cu. in. This engine was stated to weigh 268 lbs., or 4.6 lbs. per rated h.p.

An E. N. V. engine of 100 mm. (3.94 in.) bore, 130 mm. (5.12 in.) stroke, and 499.36 cu. in. total displacement, was rated 55 h.p. at 1000 r.p.m. and 75 h.p. at 1500 r.p.m The dry weight of this engine was said to be 440 lbs., or 7.3 lbs. per rated h.p.

Fig. 168. Longitudinal Section of E. N. V. Engine.

A later and more refined model, built during 1914, was rated normally 100 h.p. at 1620 r.p.m. The bore was 95 mm. (3.74 in.), the stroke 165 mm. (6.5 in.), and the total displacement 571.28 cu. in. The normal speed of the propeller was 900 r p.m. The fuel consumption was said to be .51 lbs. per h.p-hr. and the dry weight 450 lbs., or 4.5 lbs. per rated h.p. The valves were set horizontally in the cylinder head.

ESSELBÉ

The Esselbé was a seven-cylinder air-cooled rotary engine rated 65 h.p. at 1250 r.p.m. The bore was 110 mm. (4.33 in.), the stroke 120 mm. (4.72 in.), and the total displacement 486.5 cu. in. The dry weight was stated to be 167 lbs., or 2.57 lbs. per h.p.

Fig. 169. The Esselbé Rotary Engine.

The valves were one of the novel features of the Esselbé engine, the inlet being of the sleeve type and the exhaust a piston valve. The cylinders were fixed to tubular extensions from the main body of the heptagonal shaped crankcase; the lower ends, which projected for some distance into the tubular extensions, were covered by sleeve valves reciprocating over ports in the cylinder and thus admitting the incoming change. The top or outer end of the cylinder was reduced in diameter and provided with exhaust ports in the form of elongated holes between the cooling fins. These ports were uncovered by a piston valve which reciprocated inside the ported top end.

The valves operated by rods from two groups of seven eccentrics mounted upon the crankpin.

All of the working parts of the engine were of high grade steel with the exception of the sleeve valve, which was made from aluminum. The connecting rods had hollow rectangular sections and were mounted on ball bearings placed on a bushing over the crankpin. Separate oil leads conducted the oil through the crankshaft under pressure from two independent pumps. The ignition was supplied by a Bosch magneto.

ETOILE

The Etoile was a French experimental engine rated 400 h.p. at 1400 r.p.m.

FARCOT

The smaller of the air-cooled engines constructed by Farcot in Paris, France, was a two-cylinder Vee type with cylinders offset from the axis of the crankshaft. This engine developed from 8 to 10 h.p. and was said to weigh 55 lbs. A combined inlet and exhaust valve, such as was used on several other Farcot models, was operated directly from underneath by a three-step cam.

Fig. 170. End View of Two-Cylinder Farcot Engine.

Cylinder Farcot Engine.

Fig. 172. The Farcot Six-Cylinder Fan Type Engine.

One of the fan type engines built by Farcot had six cast-iron cylinders, with integral cooling flanges, which were arranged in combinations of three by staggering in such a manner that a two-throw crankshaft was used.

Fig. 173. The Farcot Eight-Cylinder Vee Type Engine.

The radial horizontal types employed eight cylinders and were built in 30, 50 and 100 h.p. sizes. The 50-h.p. engine had a 105 mm. (4.13 in.) bore, 120 mm. (4.72 in.) stroke, and a total displacement of 505.84 cu. in. This engine was said to develop 70 h.p. for short periods, but normally at 1200 r.p.m the output was 64 h.p.

The crankshaft, which had two throws 180 degrees apart, drove the propeller shaft by bevel gears. A seven-bladed horizontally mounted fan circulated air over the cylinders. The valves were of the concentric type. A gear pump supplied oil to the bearings under pressue, and two high-tension magnetos, set at one-fourth turn apart, furnished ignition. The dry weight was stated to be 242 lbs., or 3.7 lbs. per rated h.p.

The eight-cylinder air-cooled Vee type engine rated at 100/110 h.p. was quite similar to the Renault designs. The exhaust valves appeared on top and were connected by an exhaust manifold. A single carburetor was situated at one end of the engine, and at the opposite or propeller end was a fan which sucked the air around the cylinders through a casing enclosing them. This engine was provided with a compressed air starter. A rather unique piston design permitted the varying of the compression by virtue of the threaded fastenings used in place of the conventional piston pin bosses.

FARMAN

Since the war, Messrs. H. and M. Farman of France have developed two water-cooled engines in which the cylinders are arranged in pairs. One of these is an eight-cylinder Vee type rated at 200 h.p., and the other an eighteen-cylinder "W" type rated at 600 h.p. Both engines have bevel epicyclic gear reductions for the propeller, which include one fixed crown bevel, a differential spider with four satellites, and a crown bevel wheel. The valves are operated through push rods and rockers, the latter being enclosed by aluminum covers and fed directly with oil.

The dry weight of the eight-cylinder model is reported to be 700 lbs., or 3.5 lbs. per rated h.p. The oil supply is carried in the base chamber, dual ignition is furnished by magetos, and a Ragonet electric starter and an impulse magneto are fitted for starting purposes.

Fig. 174. Rear End of Farman 200-h.p. Engine.

Fig. 175. Propeller End of Farman 200-h.p. Engine.

The eighteen-cylinder type, with cylinders arranged in three rows of six, has a 120 mm. (4.72 in.) bore, 180 mm. (7.09 in.) stroke, and a total displacement of 2233.08 cu. in. The normal speed of the engine is 1800 r.p.m. There are four interchangeable valves per cylinder, and the mixture is supplied by six carburetors feeding three cylinders each.

FATAVA

The French built Fatava air-cooled engines appeared in four, eight, and sixteen-cylinder forms and were rated 45, 90, and 180 h.p., respectively, at 1300 r.p.m. A bore of 110 mm. (4.33 in.) and a stroke of 120 mm. (4.72 in.) were common to

Fig. 176. The Farman 600-h.p. Engine.

all three engines. The cylinders were of "T" head construction, two cylinders being operated from each set of valves.

The four-cylinder model was in vertical form and had a total displacement of 230.2 cu. in. This engine was stated to weigh 110 lbs., or 2.45 lbs. per rated h.p.

The eight-cylinder model was arranged in 90 degree Vee form and had a total displacement of 460.4 cu. in. This engine was said to weigh 170 lbs., or 1.89 lbs. per rated h.p.

The sixteen-cylinder engine was an "X" type with a total displacement of 920.8 cu. in., which was reported to weigh 352 lbs., or 1.95 per rated h.p.

FASEY

The Fasey was an experimental water-cooled twelve-cylinder engine rated at 200 h.p. The bore and stroke were 127 mm. (5 in.), and the total displacement was 1178 cu. in. Two Zenith carburetors were fitted. The fuel consumption was reported to be .586 lbs. per h.p-hr., and the oil consumption .045 lbs. per h.p-hr. The overall dimensions were as follows: length 42 in., width 22 in., and height 30 in.

FAURE & CRAYSSAC

A six-cylinder two-cycle air-cooled barrel type engine, estimated to develop 350 h.p. at 1400 r.p.m., was produced by Faure and Crayssac at Paris, France. The bore was 100 mm.

(3.94 in.), the stroke 180 mm. (7.09 in.), and the total displacement 518.64 cu. in. The weight was claimed to be 286 lbs., or .81 lbs. per estimated h.p.

The gas was delivered to the cylinders from the crankcase by a rotary distributor. In each cylinder were two pistons acting in opposite directions, a system of cycle claimed to give excellent scavenging effects. The crankshaft was composed of two oscillating plates, one in front and the other at the rear, therefore the connecting rods had no obliquity and consequently very little side thrust. The lubricating oil was delivered by a double piston pump, and a magneto supplied the ignition.

Mr. Crayssac also invented and built a rotary valveless engine of 80 h.p., known as the "Cyclone," that was abandoned as this power did not meet the requirements for military purposes at that time.

FIAT

The initials F. I. A. T. stand for Fabbrica Italiana Automobili Turin. The Fiat Company, which is one of the largest and best known manufacturers in Italy, probably undertook the design and construction of airplane engines as early as 1910. It was not until after the war began, however, that they produced engines in quantities. The A-12 and the A-12 Bis. models, which were among the first to be built in large numbers, were closely patterned after the German Mercedes designs, but the Fiat models brought out later exhibited a noticeable degree of originality.

One of the early Fiat engines was an air-cooled eight-cylinder 90 degree Vee type rated normally 35/40 h.p. at 1700 r.p.m. and 50 h.p. at 2000 r.p.m. The bore was 110 mm. (4.33 in.), the stroke 105 mm. (4.13 in.), and the total displacement 486.56 cu. in. One carburetor situated in the Vee fed all eight cylinders, and the valves were operated by push rods from a centrally located camshaft. The ignition for each row of four cylinders was provided by a separate magneto, and a fan was used to circulate the cooling air.

A-10. The Fiat model A-10 was a six-cylinder vertical water-cooled engine rated at 100 h.p.

Fig. 177. The Fiat Air-Cooled Eight-Cylinder Engine.

A-12. The A-12 model, although rated at 200 h.p., was guaranteed to deliver 225 h.p. at 1300 r.p.m., 245 h.p. at 1450 r.p.m., and 255 h.p. at 1500 r.p.m Tests have been reported showing that the engine developed 242 h.p. at 1300 r.p.m., 255 h.p. at 1400 r.p.m., and 268 h.p. at 1500 r.p.m. This engine had six vertical water-cooled cylinders of 160 mm. (6.3 in.) bore and 180 mm. (7.09 in) stroke, the total displacement being 1326 06 cu. in.

The cylinders were made with head and barrel integral from individual steel forgings and had valve ports and water jackets welded in place. Each cylinder had two inlet and two exhaust valves of 51.44 mm. (2.027 in.) clear diameter which seated in the cylinder head in an inclined position. The inlet valve lifted 11.78 mm. (.464 in.) and the exhaust valve 11.328 mm. (.446 in.). An overhead camshaft, that was supported in twelve bearings, operated each pair of valves from a single cam through rockers. The camshaft was lubricated by packing the casing full of heavy oil which was sufficient for twelve hours' running. The timing of the valves was as follows: inlet opened 10 degrees early and closed 50 degrees late; exhaust opened 45 degrees early and closed 15 degrees late.

Fig. 178. Inlet Side of the A-12 Fiat Engine.

The double carburetors were water-jacketed. An oil scavenging pump of the gear type was located at each end of the lower crankcase and below the rear scavenging pump was another set of gears which delivered oil to the bearings under pressure. The fuel consumption was stated to be .492 lbs. per h.p-hr., and the oil consumption .024 lbs. per h.p-hr.

The crankshaft was a conventional six-throw seven-bearing type. The connecting rods used a four-bolt cap and had "H" sections with drilled webs to which an oil pipe was clipped to lead oil to the piston pin. The pistons were made from aluminum and fitted with four top rings and one lower ring which served as an oil scraper. A centrifugal pump circulated the cooling water, and two high-tension Dixie magnetos furnished the ignition.

A-12 Bis. A later development of the A-12 engine is known as the A-12 Bis. In general the dimensions are identical, but this engine has a 4.75 compression ratio which is higher than that usually employed in the earlier model. The

Fig. 179. Longitudinal Section of Fiat A-12 Bis Engine.

Fig. 181. End View of Fiat A-12 Bis Engine.

23.071 in., and height 46.26 in.

Fig. 182. Transverse Section of Fiat A-12 Bis Engine.

A-14. This engine was brought out experimentally in June, 1917. It has since been developed and to date has probably been used more in actual flight than any other European engine of over 500 h.p.

The A-14 Fiat engine is a twelve-cylinder water-cooled 60 degree Vee type of 170 mm. (6.69 in.) bore, 210 mm. (8.27 in.) stroke, and 3488.4 cu. in. total displacement. The rated average output is 650 h.p. at 1550 r.p.m., 685 h.p. at 1650 r.p.m., and 725 h.p. at 1730 r.p.m. The compression ratio employed is 4.967, which results in a conservative brake mean effective pressure of approximately 90 lbs. per sq. in.

The individual cylinders are of steel with barrels and heads integral and have valve ports and water jackets welded in place. Two inlet and two exhaust valves of 66.5 mm. (2.618 in.) diameter are set inclined to the cylinder axis and

Fig. 183. Transverse Sections of Fiat A-14 Engine.

operated in pairs from each cam by rocker arms. A rather unique design is found in the valve spring arrangement. Two concentric springs are placed between each pair of valves in a cup which is guided on a thin tubular post on the cylinder and has lugs to receive the split washers of the valve stem. The valve timing is as follows: inlet opens 8 degrees late and closes 45 degrees late; exhaust opens 42 degrees early and closes 5 degrees late.

The crankshaft is a six-throw seven-bearing type, and the connecting rods are of the forked variety with "H" sections. Heavily ribbed aluminum pistons are fitted with three top rings and one lower oil scraper ring. The centrifugal water

pump which runs at one and one-half engine speed is provided with double outlets leading up through the crankcase to pipes connecting the cylinders. There are four spark plugs in each cylinder, the ignition being provided by four six-cylinder Dixie magnetos.

Two duplex Fiat carburetors are situated in the Vee. The forward carburetor feeds the front three cylinders of each bank and correspondingly the rear carburetor feeds the rear six cylinders. The system of lubrication is similar to that of the A-12 engine. The fuel consumption is reported to be .528 lbs. per h.p-hr., and the oil consumption .055 lbs. per h.p-hr.

Fig. 185. The Fiat A-14 Engine.

The dry weight is stated to be 1740 lbs., or 2.67 lbs. per rated h.p., and the water content of the engine 60 lbs. The overall dimensions are as follows: length over propeller hub 76.65 in., width 37.4 in., and height 48.78 in.

A-15. A Fiat twelve-cylinder 60-degree Vee type water-cooled engine, rated at 300 h.p., has been built experimentally.

This engine had a 110 mm. (4.33 in.) bore, 150 mm. (5.91 in.) stroke, and a total displacement of 1044.36 cu. in. The propeller turned at two-thirds of 2400 r.p.m, the normal speed of the crankshaft, and was mounted on a hollow shaft through which could be fired a gun situated in the Vee. The same general form of construction was carried out in the Model A-15-R, an engine of larger bore, which was developed later.

A-15-R. The Fiat Model A-15-R is a twelve-cylinder 60 degree Vee type water-cooled engine of 120 mm. (4.72 in.) bore, 150 mm. (5.91 in.) stroke, and 1240.92 cu. in. total displacement. This engine is rated normally at 400 h.p. for long runs and 430 h.p. for short runs at 2415 r.p.m. The compression ratio is 5.5. The propeller is mounted on a shaft driven through herring-bone gears and turns normally at 1600 r.p.m.

Fig. 186. The Fiat A-15-R Engine.

The cylinders are made from steel forgings, and are formed in a single block of six with a common water jacket of sheet steel welded in place. An overhead enclosed camshaft, driven at the center, operates two inlet and two exhaust valves per cylinder, the later being located on the outside of the Vee. Four carburetors are attached to the lower part of the cylinder blocks on the outside, the gas having to pass through welded-in passages to an external manifold in the Vee.

The crankshaft is a six-throw seven-bearing type, and the pistons are made from aluminum. A force-feed system of lubrication is employed, and dual ignition is provided by two magnetos mounted crosswise at the center of the engine on the outside in a very accessible position.

The fuel consumption is reported to be .485 lbs. per h.p-hr., and the oil consumption .055 lbs. per h.p-hr. The engine weighs approximately 800 lbs. The overall dimensions are as follows: length 58.19 in., width 28.89 in., and height 31.69 in.

Fig. 187. The Fiat Water-Cooled Radial Engine.

A-16. A twelve-cylinder Fiat engine, known as Model A-16, is rated normally 600 h.p. at 2300 r.p.m. The normal speed of the propeller is reduced through gearing to 1600 r. p.m. This engine has a bore of 145 mm. (5.71 in.), a stroke of 160 mm. (6.3 in.), and a total displacement of 1935.96 cu. in.

A-18. The latest Fiat development diverges from their usual vertical and Vee form of construction, the A-18 engine being a nine-cylinder water-cooled radial type rated 300 h.p. at a normal speed of 1800 r.p.m. and 320 h.p. at a maximum

speed of 2000 r.p.m. The bore is 130 mm. (5.12 in.), the stroke 150 mm. (5.91 in.), and the total displacement 1094.31 cu. in.

The cylinders are of steel and have welded-on water jackets. The inlet pipes are steel tubes, welded inside the water jacket, and meeting with the induction chamber in the crankcase at the cylinder flange. The water jackets are connected together, so that the cooling water enters the heads of the lower two cylinders and discharges at the top of the two on each side of the upper center cylinder. There are two inlet and two exhaust valves standing vertically in the cylinder head and held to their seats by leaf springs. These are operated from a single plate cam by a pull and push rod and rocker arm which acts upon a yoke between them.

The single-throw built-up crankshaft and the master connecting rod of the articulated assembly are both carried on ball bearings. The aluminum crankcase contains a passage for the charge that is mixed in a single carburetor bolted thereto. Two spark plugs are placed diagonally in each cylinder in a horizontal position, and connected to separate magnetos which are mounted crosswise at the rear. A double-piston type pump circulates the oil, and a centrifugal pump the cooling water.

The A-18 engine is reported to weigh empty 500 lbs., and with water 546 lbs. The weight per h.p. dry is therefore 1.66 lbs. and with water 1.82 lbs. The approximate overall diameter is 39.4 in. and the overall length 22.4 in.

FORD

The Ford automobile engines were frequently used by amateur aviators during the early days of flying in America. They were usually converted so as to provide a propeller drive, give more horsepower and weigh less, if possible.

FOX

The Fox airplane engines were built by the Dean Manufacturing Company of Newport, Kentucky, during 1911 and 1912. These engines operated on the two-stroke cycle, were water-cooled, and had cylinders arranged vertically. They were distinguished by the use of a special fourth port, known as an accelerator, which was directly controlled by the pilot.

This port was designed for the admission of air only, being located below the third port and accordingly admitted air to scavenge the burnt gases before the fuel charge entered the cylinder. When the accelerator was completely closed, the engine operated as the usual three-port type.

The smaller Fox engine had four cylinders and was rated 36 h.p., the bore and stroke being 3.5 in., and the total displacement 134.68 cu. in. This engine was reported to weigh 150 lbs., or 4.15 lbs. per rated h.p.

A three-cylinder model of 4 in. bore and stroke, and 150.78 cu. in. total displacement, was rated 45 h.p. at 1000 r.p.m. The dry weight was said to be 150 lbs., or 3.34 lbs. per rated h.p.

A four-cylinder engine of the same bore and stroke was rated 60 h.p. at 1000 r.p.m. The total displacement was 201.04 cu. in., and the dry weight was reported to be 190 lbs., or 3.17 lbs. per rated h.p.

A six-cylinder form with corresponding cylinder dimensions and therefore 301.56 cu. in. total displacement, was rated 90 h.p. at 1000 r.p.m. This engine was stated to weigh 280 lbs., or 3.11 lbs per rated h.p.

Four and six-cylinder engines, corresponding to the model described above in dimensions and rated outputs, were operated on the two-stroke opposed principle. The four-cylinder type was reported to weigh 175 lbs., or 2.92 lbs. per rated h.p., and the six-cylinder type 250 lbs., or 2.78 lbs. per rated h.p.

A four-cylinder model, known as the DeLuxe, was rated 50 h.p. at 1200-1300 r.p.m. The bore was 4.75 in., the stroke 4.25 in., and the total displacement 301.24 cu. in.

Fig. 188. The Fox DeLuxe Two-Cycle Engine.

The largest Fox engine had eight vertically arranged cylinders and was rated at 200 h.p. The bore and stroke were 6 in., and the total displacement 1357.2 cu. in. This engine was reported to weigh 850 lbs., or 4.25 lbs. per rated h.p.

FRAYER-MILLER

Frayer-Miller are not known to have constructed airplane engines, but their early automobile engines are of special interest as the system of direct air cooling was later copied by Pipe and other European manufacturers of aircraft engines. This consisted of a rotary fan which forced air upon the hottest portion of the cylinder, namely, the head, by means of specially designed jackets or casings.

Fig. 189. The Frayer-Miller Engine.

FREDERICKSON

The Frederickson engines, built by the World's Motor Company of Bloomington, Illinois, were two-cycle air-cooled rotary engines of five and ten cylinders and known as Model 5a and Model 10a, respectively. The bore was 4.5 in. and the stroke 4.75 in.

The five-cylinder engine was rated 70 h.p. at a normal speed of 1000 r.p.m., and reported to weigh 180 lbs., or 2.57 lbs. per rated h.p. The total displacement was 377.7 cu. in. The ten-cylinder model of 755.4 cu. in. displacement was rated at 140 h.p.

The cylinders were made with integral cooling fins from cast iron and supported from the head by steel rods. The crankcase contained the curved seats for the valves which closed the inner end of the cylinders. The valves extending into the cylinders and were operated by the oscillating motion of the connecting rods which passed through them.

The gas was drawn from the carburetor through the crankcase and oscillating valves into the inner end of the cylinders. There was no compression in the crankcase, the gas being compressed in the inner end of the cylinders and transferred by means of a by-pass to the outer ends where it was compressed and fired.

Fig. 190. The Fredrickson Five-Cylinder Rotary Engine.

FRONTIER

The Frontier Iron Works of Buffalo, N. Y., built airplane engines during 1912. These were water-cooled types of 4.125 in. bore and 4.75 in. stroke, appearing in four-cylinder vertical and eight-cylinder Vee forms.

The four-cylinder engine, which had a total displacement of 253.92 cu. in., was rated at 35 h.p. The cylinders were made from cast iron, and the valves were of the rotary type. A force feed system of lubrication was employed, Bennett carburetors supplied the mixture, and Mea magnetos the ignition.

The dry weight including equipment was reported to be 175 lbs., or 5 lbs. per rated h.p. The overall dimensions were as follows: length 32.5 in., width 17 in., and height 27.5 in.

The eight-cylinder models were rated at 55 h.p., the total displacement being 507.84 cu. in. These engines were fitted with Kingston carburetors and Bosch magnetos. The valves were of the poppet variety, and lubrication was taken care of by splash. The overall dimensions were as follows: length 37.5 in., width 24 in., and height 28 in. Some of the eight-cylinder models employed cast-iron cylinders with jackets of the same material, while others were fitted with copper water jackets. The weight of the former was said to be 315 lbs., or 5.73 lbs. per rated h.p.; and the latter 292 lbs., or 5.3 lbs. per rated h.p.

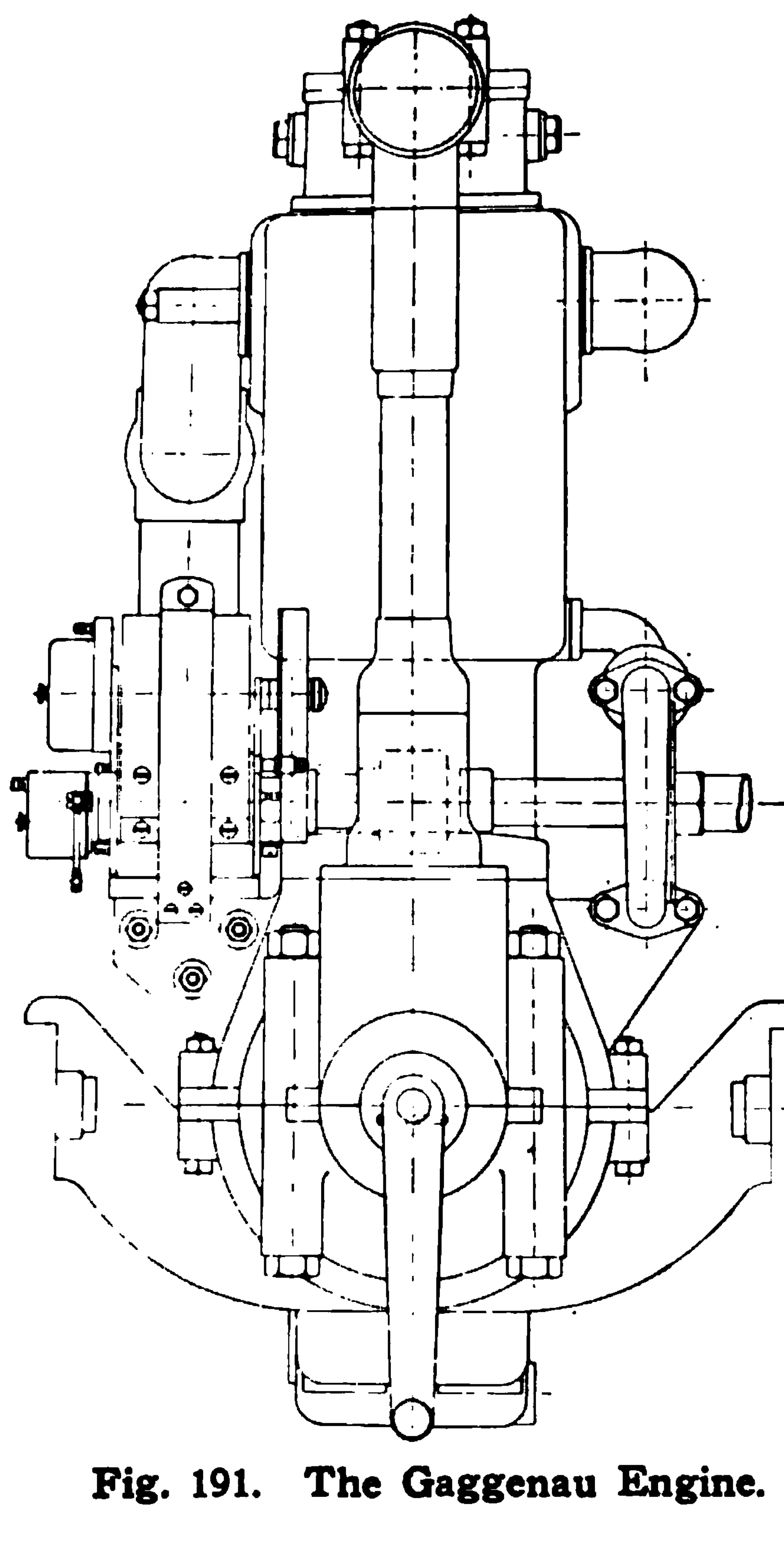


Fig. 191. The Gaggenau Engine.

GAGGENAU

The German built Gaggenau engine was a water-cooled four-cylinder vertical type having cylinders cast in pairs with integral water jackets. Each cylinder barrel was fitted with a liner pressed into place and locked at the lower end by an annular nut. The valves were vertically situated in the cylinder head and operated from an overhead camshaft driven by vertical shaft and bevel gears. The connecting rods had "H" sections and four-bolt caps. The crankshaft was supported in three bearings, those at the ends being of the annular ball type.

GALLOWAY

The Galloway Engineering Company, Ltd., of Dumfries, Scotland, was organized in 1916 for the purpose of exploiting the new B. H. P. designs. Engines with corresponding dimensions but of slightly different construction are also produced by the Siddeley-Deasy Co., of Coventry, England.

"Adriatic." The Galloway "Adriatic" is a six-cylinder vertical water-cooled engine rated 230 h.p. at 1350 r.p.m. The bore is 145 mm. (5.71 in., the stroke 190 mm. (7.48 in.), and the total displacement 1149.24 cu. in. The weight is said to be 685 lbs., or 2.98 lbs. per rated h.p.

The fuel consumption is reported as .517 lbs. per h.p-hr., and the oil consumption .0315 lbs. per h.p-hr. The mixture is furnished by two Zenith carburetors; and lubrication is of the dry sump type, a gear pump which delivers oil under approximately 20 lbs. pressure to the bearings being employed. Two Fellows EM 6 magnetos furnish dual ignition.

Fig. 192. End View of Galloway "Adriatic" Engine.

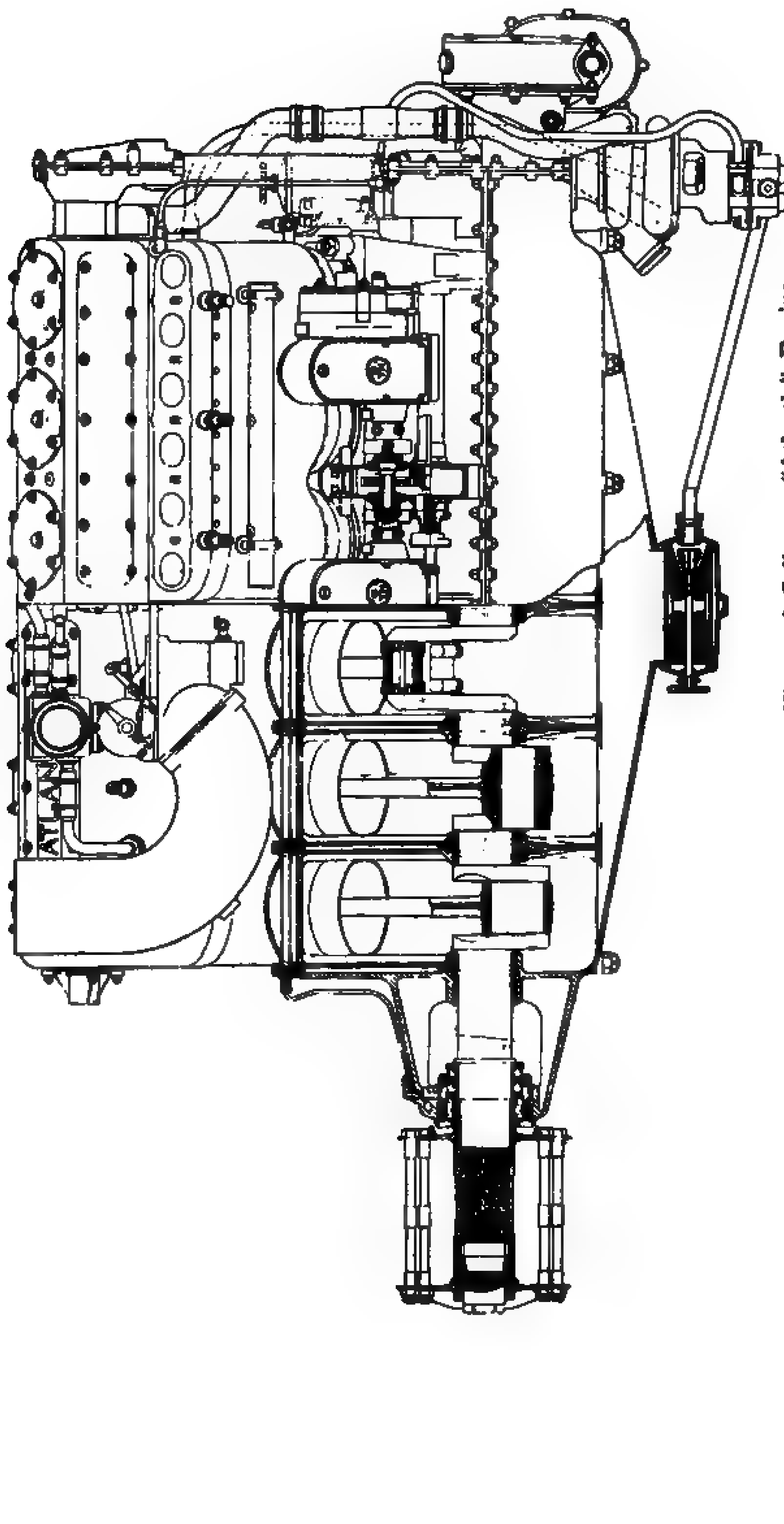


Fig. 193. Side and Sectional Views of Galloway "Atlantic" Engine.

The cylinders are constructed in groups of three, three steel cylinder barrels being screwed into a single iron casting which forms the head. A steel stamping jackets three cylinders and is made water tight by special type joints. The camshaft operates directly upon the two exhaust valves of each cylinder and is supported in an aluminum housing running the entire length of the engine. The large inlet valve is operated through a rocker arm. The valve timing is as follows: the inlet opens 7 degrees late and closes 43 degrees late; the exhaust opens 58 degrees early and closes 12 degrees late.

Fig. 194. Transverse Section of Galloway "Atlantic" Engine.

The six-throw crankshaft is supported by seven plain bearings with individual caps. The long bolts, which support the bearing caps through the steel reinforcements from underneath, are also used to hold down the cylinders. The connecting rods have "H" sections and four-bolt caps. The aluminum pistons are fitted with four rings, the one located below the wrist pin serving as an oil scraper.

"Atlantic." A double form of the "Adriatic" engine, with 2298.28 cu. in. piston displacement, is rated 500 h.p. at 1500 r.p.m. The two rows of six cylinders which set at 60 degrees, are each divided into two blocks of three. The connecting rods are of the articulated type, the stroke on the linked rod side becoming 202 mm. (7.95 in.).

The Claudel H. C. 7 carburetors are located in the Vee and two B. T. H. Type A. V. 12 magnetos are mounted on the crankcase just outside the cylinders. The fuel consumption is reported as .53 lbs. per h.p-hr., and the oil consumption as .068 lbs. per h.p-hr. The valve timing is as follows: the inlet opens 8 degrees late and closes 55 degrees late; the exhaust opens 48 degrees early and closes 16 degrees late. The total dry weight of the engine is 1210 lbs., or 2.4 lbs. per rated h.p.

GENERAL ORDNANCE

The General Ordnance Company of Derby, Conn., built an eight-cylinder Vee type water-cooled engine rated at 200 h.p. The bore was 4.75 in., the stroke 6.5 in., and the total displacement 921.52 cu. in. The dry weight of this engine was said to be 876 lbs., or 4.38 lbs. per rated h.p.

GNOME

Although the air-cooled rotary engine was originated by Farwell in America, it is due to the skillful Gnome designs of M. Laurent Seguin of France that the type attained popularity and came into general use. The Gnome engines have accordingly played an important part in the general development of aviation, particularly during 1909 and 1910, when so many important records were made with them. These designs were copied to a certain extent by several of the later rotary engine constructors. In spite of the obvious disadvantages, the Gnome, as well as several other well-known rotaries, are still

being used and no doubt will continue to be favored for certain classes of flying.

The following firms are known as authorized builders of Gnome engines: Société des Moteurs Gnôme et Rhône, 3 Rue la Boetie, Paris, France; The Gnome and Le Rhone Engine Co., Ltd., 47 Victoria St., S. W. London, England; La Societa Italiana Motori Gnome and Rhone, 73 Strada Veneria, Madonna di Compagna, Italy; General Vehicle Co., Long Island City, N. Y., U. S. A.

Fig. 195. The Gnome Seven-Cylinder Rotary Engine.

With the exception of only a few parts, the Gnome engines are made entirely from nickel steel. The cylinders have integral circumferential cooling flanges and are held in place by being clamped between the two halves of the crankcase. The crankshaft is of built-up construction; the rear section being made hollow for the purpose of piping oil to the crankpin from the plunger pump, and feeding the mixture into the crankcase from a carburetor mounted at the rear. The connecting rods are of the articulated type, and are generally made with "H" sections. The master connecting rod is mounted upon large ball bearings. The fixed crankshaft, which supports the rotating mass of crankcase and cylinders

upon ball bearings, provides a mounting for a battery of individual cams (one for each cylinder) near the propeller end.

The original Gnome engines had two valves, the exhaust being placed in the cylinder head and the inlet in the head of the piston, where it was operated automatically. The Gnome monosoupape type was placed on the market in 1913. This engine, as the name signifies, had only one valve. This was situated in the cylinder head and functioned principally as an exhaust, but as an inlet by the admission of air during the suction stroke. A rich mixture entered the combustion chamber from the crankcase through ports in the lower end of the cylinder, when the piston was at the lower end of the stroke.

The first Gnome design had five cylinders and was rated 34 h.p. at 1300 r.p.m. The bore and stroke were 100 mm. (3.94 in.), and the total displacement was 209.2 cu. in. The weight was stated to be 132 lbs., or 3.9 lbs. per rated h.p. This engine was shortly superseded by the seven-cylinder 50-hp. model.

Omega. A seven-cylinder rotary engine, of 110 mm. (4.33 in.) bore, 120 mm. (4.73 in.) stroke, and 488.5 cu. in. total displacement, was rated 50 h.p. at 1200 r.p.m. The fuel consumption was reported to be .59 lbs. per h.p-hr., and the oil consumption .185 lbs. per h.p-hr. The dry weight, including Bosch magnetos, was said to be 172 lbs., or 3.44 lbs. per rated h.p. The outside diameter was 33 in. and the overall length 31 in.

Sigma. A seven-cylinder engine of 120 mm. (4.72 in.) bore and stroke, and a total displacement of 579.11 cu. in., was rated 60 h.p. at 1200 r.p.m. The weight was reported to be 192 lbs., or 3.2 lbs. per rated h.p. The outside diameter was 34.2 in. and the overall length 44.4 in.

Gamma. A seven-cylinder rotary engine of 130 mm. (5.12 in.) bore, 120 mm. (4.72 in.) stroke, and 679.84 cu. in. total displacement, was rated 70 h.p. at 1200 r.p.m.

Lambda. A seven-cylinder rotary engine of 124 mm. (4.88 in.) bore, 140 mm. (5.52 in.) stroke, and 722.75 cu. in. total displacement, was rated 80 h.p. at 1200 r.p.m The fuel consumption was said to be .59 lbs. per h.p-hr., and the oil consumption .185 lbs. per h.p-hr. The weight was reported

to be 207 lbs., or 2.59 lbs. per rated h.p. The outside diameter was 36.3 in. and the overall length 44 in.

Delta. A nine-cylinder rotary engine of 124 mm. (4.88 in.) bore, 150 mm. (5.90 in.) stroke, and 993.23 cu. in. total displacement, was rated 100 h.p. at 1200 r.p.m. The fuel consumption was reported to be .59 lbs. per h.p-hr., and the oil consumption .185 lbs. per h.p-hr. The total dry weight was said to be 297 lbs., or 2.97 lbs. per rated h.p. The outside diameter was 40.2 in. and the overall length 45.3 in.

Omega-Omega. A fourteen-cylinder rotary engine, a double form of the Omega type with a total displacement of 973 cu. in., developed 120 h.p. at 1200 r.p.m. The dry weight was reported to be 310 lbs., or 2.58 lbs. per h.p. The outside diameter was 32.5 in. and the overall length 49.5 in.

Gamma-Gamma. A double form of the Gamma type, with fourteen cylinders and 1359.68 cu. in. total displacement, was rated 130/140 h.p. at 1200 r.p.m. The dry weight was said to be 287 lbs., the outside diameter 19.47 in., and the overall length 39.6 in.

Sigma-Sigma. A fourteen-cylinder engine, composed of two rows of Sigma type cylinders and therefore having a total displacement of 1158.22 cu. in., was rated 120 h.p. at 1200 r. p.m The dry weight was reported as 298 lbs., or 2.48 lbs. per rated h.p. The outside diameter was 34.2 in. and the overall length 49.8 in.

Lambda-Lambda. An engine, with a double set of seven cylinders of the Lambda type and having a total displacement of 1445.5 cu. in., was rated 160 h.p. at 1200 r.p.m. The dry weight was said to be 396 lbs., or 2.46 lbs. per rated h.p. The outside diameter was 36.7 in. and the overall length 49.8 in.

Delta-Delta. A double form of the Delta type, having eighteen cylinders and a total displacement of 1986.46 cu. in., was rated 200 h.p. at 1200 r.p.m. This engine was stated to weigh 540 lbs., or 2.7 lbs. per rated h.p. The outside diameter was 40.2 in. and the overall length 54.1 in.

Type A. The first Gnome monosoupape design had seven cylinders and was rated 80 h.p. at 1200 r.p.m. The bore was 110 mm. (4.33 in.), the stroke 150 mm. (5.91 in.), and the total displacement 609.21 cu. in. The outside diameter was 35.3 in. and the overall length 39.3 in.

Type B-2. A nine-cylinder monosoupape type, rated 100 h.p. at 1200 r.p.m., employed the same cylinders as the Type A engine and therefore had a total displacement of 783.27 cu. in. This engine was reported to weigh 272 lbs., and to have the following overall dimensions, diameter 37.4 in. and length 42.3 in.

Fig. 197. Section of Gnome Monosoupape Rotary Engine.

Type N. A nine-cylinder monosoupape rotary engine, that was developed during the war, had a 115 mm. (4.53 in.) bore, 170 mm. (6.69 in.) stroke, and a total displacement of 970.38 cu. in. It was normally rated 165 h.p. at 1350 r.p.m. and delivered at maximum output 170 h.p. The compression ratio was 5.45 to 1. An excessive consumption was once reported as 1.09 lbs. of fuel per h.p-hr., and .12 lbs. of oil per

h.p-hr. This engine was equipped with two magnetos, and was said to weigh 290 lbs., or 1.76 lbs. per rated h.p.

An eighteen-cylinder engine, a double form of Type N, was rated at 300 h.p. The total displacement was 1940.76 cu. in., and the dry weight was stated to be 600 lbs., or 2 lbs. per rated h.p. This engine measured overall 37 in. diameter and 53.2 in. length.

A monosoupape engine, rated 190 h.p. at 1300 r.p.m., employed eleven of the Type N cylinders and therefore had a total displacement of 1186.02 cu. in. The dry weight was reported to be 380 lbs., or 2 lbs. per rated h.p.

The Gnome Engine Co. has experimented with a twenty-cylinder air-cooled radial design, the only Gnome model on record not using rotating cylinders. In this engine the cylinders were arranged in four rows of five. The bore was 140 mm. (5.51 in.), the stroke 170 mm. (6.69 in.), and the total displacement 3190.4 cu. in. The estimated output was 600 h.p. at 1400 r.p.m. and 800 h.p. at 1700 r.p.m. The outside diameter was 42.3 in. and the overall length 59.1 in.

GOBE

The Gobe was an experimental two-cycle engine built in France.

GOBRON-BRILLÉ

The Gobron-Brillé engines were early French designs of the eight-cylinder water-cooled "X" type. Each cylinder had two pistons that were driven apart during the explosions between them. The connecting rods of inner pistons were hinged to the crankshaft in the unusual manner, while the outer pistons delivered their power to opposite outer cranks by long connecting rods passing outside the cylinder proper, but enclosed in an oil tight housing.

The automatic inlet valves were fed from a single carburetor. The exhaust valve operating mechanism had the only external moving parts; a double rocker arm, placed over the exhaust valves of each adjacent pair of cylinders, obtained its movement through a lever on the other end of its shaft, which had a shoe running in one of the two grooves of the double cam that was keyed to the crankshaft. At each revolution of the crankshaft the shoes alternated position on the

cam at points where the grooves crossed as in a figure eight. Ignition was provided by two magnetos. A gear pump circulated the oil, and a centrifugal pump the cooling water.

The smaller Gobron-Brillé engine was rated 54 h.p. at 1400 r.p.m. The bore was 90 mm. (3.54 in.), the stroke 160 mm. (6.3 in.), and the total displacement 496 cu. in. The weight was stated to be 330 lbs., or 6.11 lbs. per rated h.p.

The larger model was rated 102 h.p. at 1400 r.p.m. and reported to weigh 350 lbs., or 3.42 lbs. per rated h.p. The bore was 120 mm. (4.72 in.), the stroke 200 mm. (7.87 in.), and the total displacement 1101.6 cu. in.

Fig. 198. The Gobron-Brillé "Y" Type Engine.

GOEBEL

The factories of Georg Goebel at Darmstadt, Germany, which specialized in the manufacture of ticket-punching machinery, during and after the war, built four rotary models; the larger engine, known at Type III, being used to a lim-

ited extent in active service before the signing of the Armistice.

The principal feature of the Goebel engines was the valve gearing. The exhaust valves were controlled from a single stationary cam; the tappet plungers, connected with the push rods and rocker levers, swung so that they passed the cam every other revolution. A half-compression cam, to be operated from the pilot's seat, was provided for easy starting and control.

Lubrication was of the pressure feed type. The inlet valves, situated in the tops of the pistons, were provided with counterweights. The pistons were built up in two sections, the lower section acting only as a guide.

Type VI. The 30/40-h.p. model had seven cylinders of 94 mm. (3.70 in.) bore, 95 mm. (3.74 in.) stroke, and a total displacement of 281.49 cu. in. The weight was said to be 121 lbs. The engine operated from 1150 r.p.m. minimum to 1200 r.p.m. maximum, and consumed nearly 32 lbs. of fuel and 2 lbs. of oil per hr. The compression ratio was 4.6.

Both inlet and exhaust valves were mechanically operated and had a clear diameter of 34 mm. (1.34 in.). The cylinders were provided with flanges for mounting. A Pallas carburetor supplied the mixture through induction pipes, and a Bosch magneto provided ignition. The overall dimensions were as follows: outside diameter 25.98 in., and length 35.43 in.

Type V. A larger seven-cylinder rotary engine, which operated at the same speeds, was rated at 50 to 65 h.p. This engine had a 105 mm. (4.13 in.) bore and stroke, and a total displacement of 387.24 cu. in. The weight was reported to be 165 lbs., and the approximate fuel and oil consumption 48 and 10 lbs. per hr., respectively. The compression ratio was 5.2.

The cylinders were mounted by a threaded joint. Both valves are mechanically controlled, their diameter being 43 mm. (1.69 in.). The gas was fed through induction pipes from a SB-V-AL carburetor, and a Bosch magneto supplied the ignition. The overall diameter was 27.56 in. and the length approximately 38 in.

Type II. The seven-cylinder 100/110-h.p. model had a 138 mm. (5.43 in.) bore, 150 mm. (5.91 in.) stroke, and a total

displacement of 958.02 cu. in. The weight was said to be 271 lbs., and the approximate consumption of fuel and oil 77 and 14 lbs. per hr., respectively. The engine operated from 1150 r.p.m. minimum to 1200 r.p.m. maximum. The compression ratio was 4.5.

The cylinders were retained by a bayonet type joint. This model, as well as Type III, employed automatically operated inlet valves. The inlet valves were 54 mm. (2.13 in.) diameter and the exhaust valves 59 mm. (2.32 in.) diameter in both Type II and III engines. Further, the induction systems were alike; the gas being delivered to the cylinders through the crankshaft and case. The outside diameter of the Type II design was 38.5 in. and the overall length approximately 40 in.

Type III. The nine-cylinder model developed from 200 to 230 h.p. at corresponding speeds. The bore was 138 mm. (5.43 in.), the stroke 290 mm. (11.41 in.), and the total displacement 2378 cu. in. The weight was said to be 403 lbs. This engine consumed .62 lbs. of fuel per h.p-hr., and .099 lbs. of oil per h.p-hr. The compression ratio was 5.2. The outside diameter measured 45 in. and overall length 44.5 in.

GRADE

Grade, in Germany, built engines only for his own monoplane.

GREEN

The Green Engine Co., Ltd., of London, for a number of years prior to the war, built water-cooled airplane engines credited as being among the most reliable produced in England at that time. The cylinders were made of cast steel, turned inside and out, and fitted with copper water jackets which were made tight by rubber rings. Long bolts through the crankcase were used for holding down the cylinders as well as the crankshaft bearing caps. A seven-bearing camshaft, together with the valve rocker arms, were enclosed overhead; the camshaft being driven from the crankshaft by a vertical shaft and skew bevel gears. The valves stood vertically in the cylinder head and seated on removable cages.

The crankshafts were arranged for plain bearings on either side of a crank-throw and double-row ball bearings

were provided for taking the propeller thrust. Oil under approximately 20 lbs. per sq. in. pressure was delivered to the bearings by a gear pump, a gear pump with bronze wheels being also used to circulate the cooling water. The ignition on all Green engines was furnished by magnetos.

C-4. A four-cylinder vertical water-cooled Green engine, rated 32 h. p. at 1200 r.p.m., had a 105 mm. (4.13 in.) bore, 120 mm. (4.73 in.) stroke, and a total displacement of 253.44 cu. in. The fuel consumption was reported to be .503 lbs. per h.p-hr., and the dry weight 160 lbs., or 5 lbs. per rated h.p. The flywheel weighed 23.5 lbs. additional.

Fig. 199. The Green 120-h.p. Engine.

D-4. The four-cylinder vertical water-cooled Green engine, rated 60 h.p. at 1100 r.p.m,, had a bore of 140 mm. (5.51 in), a stroke of 146 mm. (5.75 in.), and a total displacement of 548.78 cu. in. The consumption of fuel was reported to be .59 lbs. per h.p-hr., and that of oil .11 lbs. per h.p-hr. The total weight, including a 37 pound flywheel, was approximately 260 lbs.

E-6. A six-cylinder vertical water-cooled Green engine of 140 mm. (5.51 in.) bore, 152 mm. (5.98 in.) stroke, and a total displacement of 855.54 cu. in., was rated at 100 h.p. It was reported that the engine developed 120 h.p. at 1250 r.p.m. and consumed .48 lbs. of fuel per h.p-hr. The total dry weight was said to be 447 lbs., the engine being fitted with a flywheel weighing 37 lbs.

Eight-Cylinder. An eight-cylinder vertical water-cooled Green engine, rated 82 h.p. at 1100 r.p.m., had a 116 mm.

Fig. 201. Transverse Section and End View of Green Engine.

(4.57 in.) bore, 140 mm. (5.51 in.) stroke, and a total displacement of 723.04 cu. in.

Six, twelve, and eighteen-cylinder water-cooled engines, rated 150, 300, and 450 h.p., respectively, at 1200 r.p.m., were built with 142 mm. (5.59 in.) bore and 178 mm. (7.01 in.)

Fig. 202. The Green 300-h.p. Engine.

stroke. The six-cylinder engine was a vertical type, having a total displacement of 1032.24 cu. in. The twelve-cylinder model, with a total displacement of 2064.48 cu. in. had cylinders arranged in Vee form. The eighteen-cylinder type of 3096.72 cu. in. total displacement was in "W" form, being composed of three rows of six cylinders each.

Fig. 203. The Green 450-h.p. Engine.

GRÉGOIRE.

The Grégoire four-cylinder vertical water-cooled engines were built in France in 1910. An interesting feature of these designs was the thermo-syphon circulating system and the integral radiator which reduced the amount of water to be carried to a minimum. The radiator consisted of four banks of small copper tubes terminating in a header at the top and bottom, the forward sections having two rows of tubes and the rear section only one. The upper header extended outward for a distance across the cylinder heads and received the water from a connection close to the valves while the lower headers were attached at right angles to the lowest part of the jacket.

The smaller engine was rated 26 h.p. at 1500 r.p.m. and reported to weigh 174 lbs., or 6.6 lbs. per rated h.p The bore was 92 mm. (3.62 in.), the stroke 140 mm. (5.61 in.), and the total displacement 228.08 cu. in.

The larger Grégoire engine was rated 51 h.p. at 1000 r.p.m. and reported to weigh 242 lbs., or 4.7 lbs. per rated h.p. The bore was 130 mm. (5.12 in.), the stroke 140 mm. (5.51 in.), and total displacement 453.44 cu. in.

Fig. 204. The Grégoire Four-Cylinder Engine.

GREY EAGLE

The Grey Eagle engines were air-cooled vertical types built in America during 1911 and 1912. The cylinders were of cast-iron construction. A force feed system of lubrication was employed, and Bosch magnetos supplied the ignition.

The four-cylinder model was rated at 40 h.p.; the bore being 4.25 in., the stroke 4.5 in., and the total displacement 255.36 cu. in. The engine was equipped with a Schebler carburetor. The total dry weight was reported to be 185 lbs., or 4.63 lbs. per rated h.p. The overall dimensions were as follows: length 45 in., width 18 in., height 25.5 in.

A six-cylinder model, having the same bore and stroke and therefore a total displacement of 383 cu. in., was rated at 60 h.p. This engine was fitted with a Rayfield carburetor, and reported to weigh 235 lbs., or 3.92 lbs. per rated h.p. The overall dimensions were as follows: length 51 in., width 16 in., height 25.5 in.

A later six-cylinder model of 4 in. bore, 4.5 in. stroke, and 339.3 cu. in. total displacement, was rated 50 h.p.

at 1100 r.p.m. The weight of this engine was reported to be 260 lbs., or 5.2 lbs. per rated h.p.

GYRO

The Gyro Motor Company, 774 Girard St., Washington, D. C., was one of the first American firms to design and build a successful air-cooled rotary engine. This work was under the direction of Emile Berliner, who had also fostered the design and construction of the Adams-Farwell engines which were to be used in the Berliner helicopter.

The Old Gyro, as it is now generally referred to, was a seven-cylinder air-cooled rotary engine, rated 50 h.p. at 1500 r.p.m. This engine weighed 160 lbs., or 3.2 lbs. per rated h.p. The bore was 4.3125 in., the stroke 4.75 in., and the total displacement 485.66 cu. in. The fuel consumption was said to be .72 lbs. per h.p-hr., and the oil consumption .17 lbs. per h.p-hr.

The Old Gyro had an exhaust valve in the cylinder head, which was controlled by means of a push rod and rocker; and an intake valve of the poppet variety, located in the piston. The latter was operated by a lever that made contact with a

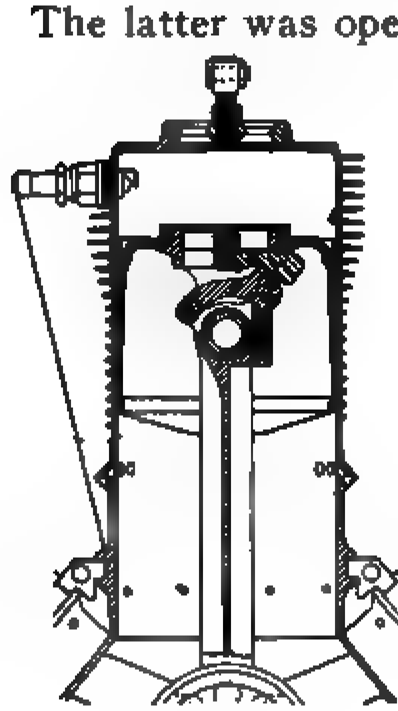


Fig. 205. Section

Fig. 206. The Gyro "Duplex" Model K Engine.

Fig. 207 Valve Mechanism of the Model K Gyro "Duplex" Engine.

second lever pivoted on the connecting rod and moved through the effect of centrifugal force.

Some of the Old Gyro engines were fitted with Moore tubular cooling fins. There were 36 per cylinder in a vertical position, but ordinarily the fins were cut upon the cylinder as a continuous screw thread. The steel cylinders were held in position by clamping between the halves of the crankcase. The connecting rods had "H" sections. Ball bearings were used throughout, a double-row type being provided at the propeller end to carry the thrust.

Fig. 208. Longitudinal Section of the Gyro "Duplex" Type.

In 1914, the Gyro Motor Company placed on the market improved models, known as the "Duplex" Type. A duplex cam, from which the name was derived, on one side operated the usual exhaust valve in the cylinder head through a push

rod and rocker; and from the other side, a slide valve intake mechanism which was attached to the outside of the cylinder about two inches above the piston at the lower end of the stroke. The ports in the cylinder, which communicated with the inlet gas conduits through the slide valve, also served as auxiliary exhaust ports. All "Duplex" models had a cylinder bore of 4.5 in. and a stroke of 6 in.

Model J. The Model J. Gyro "Duplex" engine had five cylinders and was rated 50 h.p. at 1250 r.p.m. The total displacement was 477.12 cu. in., and the engine was reported to weigh 170 lbs., or 3.4 lbs. per rated h.p.

Model K. The "Duplex" type, known as Model K, was rated 90 h.p. at 1250 r.p.m. This engine had seven cylinders with a total displacement of 667.97 cu. in. The weight was said to be 215 lbs., or 2.4 lbs. per rated h.p.

No. 209. The Gyro "Duplex" Model L Engine.

Model L. A nine-cylinder "Duplex" type engine, known as Model L, was rated 110 h.p. at 1200 r.p.m. This engine had a total displacement of 858.82 cu. in. and was reported to weigh 270 lbs., or 2.45 lbs. per rated h.p. The fuel consumption was said to be .79 lbs. per h.p-hr., and the oil consumption .16 lbs. per h.p-hr.

HAACKE

Several types of air-cooled airplane engines are built in the Haacke factory at Johannisthol, Berlin, Germany. The three-cylinder 30/35 and 35/40-h.p. fan types are similar to some of the Anzani engines. These models are equipped with battery ignition, and employ automatically operated inlet valves. The crankshafts are mounted in ball bearings, and lubrication is by pressure feed. All Haacke engines operate normally at 1400 r.p.m.

Fig. 210. The 35/40-h.p. Fan Type Haacke Engine.

Fig. 211. The 55/60-h.p. Five-Cylinder Haacke Engine.

Four radial types have the following output: 55/60-h.p., 60/70-h.p.; 80/90-h.p.; and 120 h.p. These engines are equipped with magneto ignition, the larger ones having valves in the cylinder head, both mechanically operated. The 55/60-h.p. model has five cylinders and the 120-h.p. model ten.

Fig. 212. The Haacke 30/35-h.p. Engine.

The Haacke Company also build two-cylinder air-cooled opposed type engines in two sizes, the smaller having a 112 mm. (4.41 in.) and 140 mm. (5.51 in.) bore and stroke, and a total displacement of 168.32 cu. in. This engine is said to develop 28 h.p. at 1300 r.p.m.

The larger engine, rated 30/35 h.p., has a 120 mm. (4.72 in.) bore, 140 mm. (5.51 in.) stroke, and a total displacement of 192.82 cu. in. The weight of this engine is reported to be 132 lbs., and the width overall approximately 43 in.

The cylinders are made from semi-steel castings with integral cooling flanges. The valves are situated in the cylinder head and operated by means of push rods and rocker arms. The crankcase is of aluminum and contains a wet sump in which are immersed plunger pumps operated by the two inlet cams. The pumps operate independently, and squirt oil upon the crankshaft which distributes it by centrifugal action. The crankshaft has two throws, and the cylinders are staggered 3.5 in.

HALL-SCOTT

The Hall-Scott Motor Car Company, with general offices in San Francisco and factories at Berkeley, California, began specializing in the construction of airplane engines in 1911. They have since produced a number of water-cooled vertical and Vee types that have all been fitted with direct driven propeller. Mr. E. J. Hall, Production Manager and Chief Engineer, was one of the co-designers of the Liberty engine, and

was in charge of the production of these engines during the greater part of the war.

A-1. One of the early Hall-Scott models, rated at 32 h.p., was a four-cylinder vertical water-cooled engine of 4 in. bore, 5 in. stroke, and 251.32 cu. in. total displacement. This engine was reported to have regularly developed 40 h.p. at 1500 r.p.m.

The cylinders had cast-iron heads with cored water passages, and a sheet-steel water jacket pressed over the barrel. They were held down by long studs from lugs on the cylinder head, and each was fitted with a single overhead inlet and exhaust valve operated by push rods and rockers. The crankshaft was made from a hand forging and had three plain bearings. The connecting rods were also hand-forged, and the grey-iron pistons were fitted with three rings.

The lubricating oil was forced to the camshaft and distributed to all the main bearings by a gear pump. It returned through the inlet manifold to the main crankcase where a level was maintained for the connecting rods to dip. Stromberg carburetors supplied the mixture, and Mea magnetos the ignition. The dry weight was reported to be 165 lbs. The overall dimensions were as follows: length 39 in., width 17.5 in., and height 28 in.

A-2. The Hall-Scott Model A-2 engine had eight cylinders in 90 degree Vee arrangement and was rated 60 h.p. at 1400 r.p.m. The bore and stroke were 4 in., and the total displacement 402.08 cu. in.

The cylinders were constructed of semi-steel and had valves in the cylinder head operated by push rods and rockers. The engine was equipped with Stromberg carburetors and Mea Magnetos, and employed a force feed system of lubrication. The total dry weight was said to be 260 lbs., or 4.33 lbs. per rated h.p. The overall dimensions were as follows: length 42 in., width 24 in., and height 28 in.

A-3. Except for a 1 in. longer stroke, the A-3 engine was practically the same as the Model A-2. This engine had a total displacement of 502.64 cu. in. and was rated 80 h.p. at 1400 r.p.m. The total dry weight was reported to be 290 lbs., or 3.63 lbs. per rated h.p.

A-4. A still larger eight-cylinder 90 degree Vee type engine, of practically the same form of construction, was built

with a 5 in. bore and stroke, and a total displacement of 785.4 cu. in. The A-4 engine was rated 100 h.p. at 1200 r.p.m. and said to develop 120 h.p. at 1500 r.p.m.

The cylinders were of practically the same design as the earlier models, the valves being located in the cylinder head and operated through push rods and rockers. The inlet and exhaust valve each had a clear diameter of 2.5 in. The crankshaft was supported in five plain bearings, and dual ignition was furnished by Bosch magnetos. The total dry weight was reported to be 535 lbs., or 5.35 lbs. per rated h.p.

A-5. The A-5 Hall-Scott type was a six-cylinder vertical water-cooled engine of 5 in. bore, 7 in. stroke, and 824.67 cu. in. total displacement. This engine was rated 125 h.p. at 1250 r.p.m. and reported to weigh 525 lbs., or 4.2 lbs. per rated h.p.

The cylinders were cast from iron with water jackets integral and held down in the usual manner by long studs from lugs on the cylinder head. The Model A-5 engine employed an overhead camshaft that operated, through rocker arms, two valves which were inclined to the vertical axis of the cylinder. The inlet manifold was both water and oil jacketed. The crankshaft was mounted in seven plain bearings, and the pistons were made of cast iron. Dual ignition was supplied by magnetos.

Fig. 213. Inlet Side of Hall-Scott A-5-a Engine.

A-5-a. A slightly larger six-cylinder vertical engine, known as the Model A-5-a, was built with a 5.25 in. bore, 7 in. stroke, and a total displacement of 909.22 cu. in. This engine was rated at 150 h.p. and developed 165 h.p. at 1475 r.p.m. The compression ratio was 4.6, and the brake mean effective pressures averaged 97.5 lbs. per sq. in. The oil consumption was reported to be .029 lbs. per h.p hr., the pressure maintained by the gear pump varying from 10 to 35 lbs. at normal r.p.m. Duplex Zenith carburetors were fitted.

The Model A-5 form of construction was employed throughout. Both inlet and exhaust valves had a clear diameter of 2.25 in. and a .375 in. lift. The timing of the valves was as follows: the inlet opened 15 degrees late and closed 45 degrees late; the exhaust opened 54 degrees early and closed 10 degrees late. The length over the propeller hub was 62.5 in., the overall width 24 in., and the height 43.875 in.

Fig. 214. End and Sectional Views of Model A-5-a.

A-7. A four-cylinder vertical engine, using the same cylinders as the A-5 model and therefore having a total displacement of 549.78 cu. in., was rated from 90 to 100 h.p. at 1400 r.p.m. This engine was reported to weigh 410 lbs.

Zenith carburetors were fitted, and dual ignition was supplied by two Dixie magnetos. The connecting rods had "H" sections and employed two-bolt caps. The aluminum pistons had six ribs underneath the head, and were fitted with three rings.

The gear pump forced the oil frcm the sump, through a strainer, to the jacket around the inlet manifold, and thence to the main distributor pipe in the crankcase. There was also an independent direct-drive rotary oiler, which fed to each cylinder according to the speed of the engine. A hand adjusted sight feed permitted the amount to be regulated.

A-7-a. A four-cylinder vertical engine, having the same cylinders as the A-5-a model and therefore a total displacement of 606.14 cu. in., was rated 100 h.p. at 1400 r.p.m. This engine was said to develop 110 h.p. at the above speed and weigh 420 lbs., or 3.81 lbs. per h.p.

The usual individual semi-steel cylinder construction was employed, an overhead camshaft operating through rocker arms two valves of 2.25 in. diameter and .375 in. lift. An oil pressure of 10 lbs. was maintained by a gear pump, the oil consumption being reported as .039 lbs. per h.p-hr. Either Miller or Zenith carburetors were fitted. The average fuel consumption was said to be .62 lbs. per h.p-hr.

Fig. 215. Exhaust Side of Hall-Scott A-7-a Engine.

The crankshaft was supported in five plain bearings, and the connecting rods had "H" sections and two-bolt caps. The aluminum pistons were fitted with three rings above the wrist pin. The circulation of the cooling water was by a centrifugal pump having a bronze impeller.

A-8. The Hall-Scott Model A-8 was designed and ready for test before May 1, 1917, when Mr. Hall was called to Washington to assist in the Aircraft Production Program. This was a twelve-cylinder 60 degree Vee type of 5 in. bore, 7 in.

Fig. 216. Transverse Section of Model A-8 Hall-Scott Engine.

stroke, and 1649.34 cu. in. total displacement. The output was said to be 450/500 h.p., and the weight approximately 1000 lbs.

The cylinders corresponded to those used in the A-5 and A-7 models. The crankshaft had seven plain bearings, and the connecting rods were of "H" section. A water-pump, driven from each camshaft drive shaft, circulated the cooling water to each bank of cylinders independently. Ignition was by two magnetos, two spark plugs per cylinder being provided.

L-4 and L-6. The L-4 and L-6 models are post war developments, closely resembling the Liberty, since Liberty cylinders and valve gear are used. The bore is therefore 5

[illegible]

in., the stroke 7 in., and the compression ratio approximately 5.4.

The L-4 model is rated at 125 h.p., but develops normally 130 h.p. at 1675 r.p.m. The total displacement is 549.78 cu. in., and the weight is said to be 380 lbs., or 3.05 lbs. per rated h.p.

The L-6 engine, of 825.67 cu. in. displacement, is normally rated at 200 h.p., and said to develop 224 h.p. at 1700 r.p.m. and 244 h.p. at 1830 r.p.m. The fuel consumption is reported to be .55 lbs. per h.p-hr., Miller multi-jet carburetors with barrel throttles furnishing the mixture. The oil supply is carried in the base chamber. Circulation is by a gear pump situated in the sump and delivering approximate-

Fig. 218. Timing End Hall-Scott L-6 Engine.

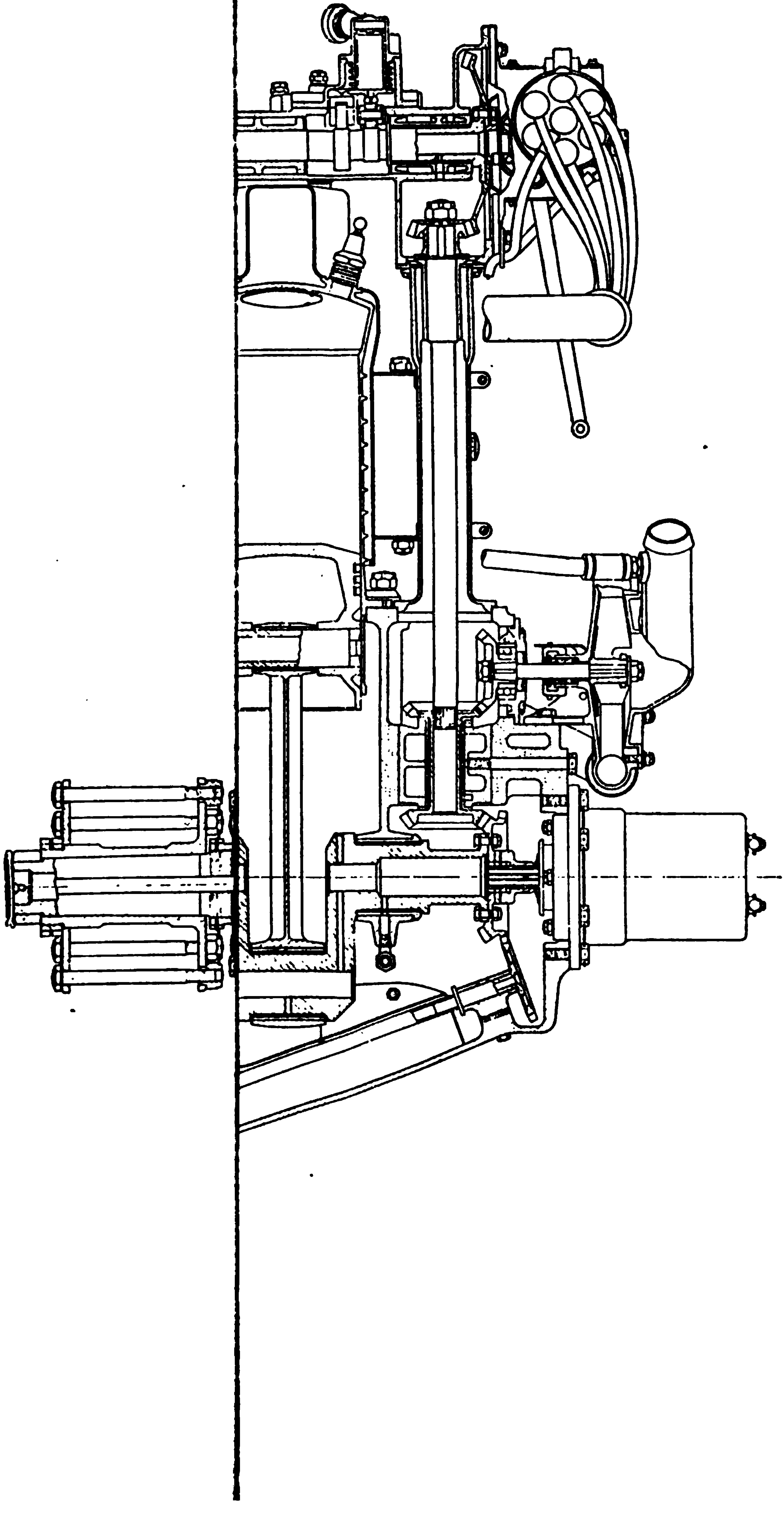


Fig. [illegible]. Exhaust Side of Hall-Scott L-6 Engine.

ly 40 lbs. pressure to the main bearings. Another pump is employed to supply fresh oil to the system.

The crankshaft is a conventional six-throw seven-bearing type supported by individual bearing caps. The connecting rods have "H" sections and employ four-bolt caps. A Liberty piston, with the addition of a deep groove and oil holes below the bottom ring, is used. A Delco battery system, with generator and distributor, furnishes the ignition. The dry weight is reported to be 546 lbs., and the water content of the engine approximately 25 lbs. The overall dimensions are as follows: length to the end of the propeller hub 65 in., width of the supports 18.25 in., and the height 44 in.

Fig 222. Propeller End of Hall-Scott L-6 Engine.

HAMILTON

The Hamilton was an eight-cylinder Vee type water-cooled engine distinguished by its unusual valve operating mechanism. The valves were in the cylinder head and had the camshaft and operating mechanism super-imposed upon them.

HANSA

The Hansa Lloyd Werke A. G. of Bremen, Germany, have built a sixteen-cylinder airplane engine described as developing 360 h.p. at 1400 r.p.m. The bore was 127 mm. (5 in.), the stroke 178 mm. (7.01 in.), and the total displacement 2202.24 cu. in. The weight was 1069 lbs., or 2.97 lbs. per h.p.

Fig. 223. The Hamilton Vee Type Engine.

HANSEN AND SNOW

A four-cylinder vertical water-cooled engine was designed and built by W. G. Hansen and L. L. Snow at Pasadena, California, during 1910. This engine was flown in one of the early Wright bi-planes and later used for an extended period in an airship by Roy Knabenshue. L. L. Snow, one of the co-designers and builders of this engine, has been an officer and pilot in U. S. Air Service since the early days of the war. Shortly after the signing of the Armistice, he was placed in charge of cooling systems development at the Engineering Division, McCook Field, Dayton, Ohio.

Fig. 224. The Hansen and Snow Engine.

The Hansen and Snow engine was rated 35 h.p. at 1200 r.p.m. The bore was 4 in., the stroke 4.5 in., and the total displacement 226.2 cu. in. The compression ratio was 5 to 1. The dry weight (without flywheel) was stated to be 105 lbs., or 3 lbs. per rated h.p. The approximate overall dimensions were as follows: length 24 in., width 11 in., and height 24 in.

The cylinders were made from cast iron, and had copper water jackets electrolitically deposited. In the dome shaped cylinder head, inclined at 60 degrees, were inlet and exhaust valves of 2.25 in. clear diameter. They were operated from an overhead camshaft by rocker arms, Hess-Bright ball bearings being employed for rollers and to support the camshaft.

The crankshaft was supported in five bearings, and the connecting rods had "H" sections. The pistons were made from cast iron with ribs underneath the head. Lubrication was of the dry sump type, a reserve supply of oil being carried in the base and the pressure feed to the bearings maintained by a gear pump. A Stromberg carburetor furnished the mixture, and a Bosch magneto the ignition.

HARDY-PADMORE

The Hardy-Padmore was a five-cylinder radial engine rated at 100 h.p. The bore and stroke were 4 in., and the total displacement 251.3 cu. in.

HARROUN

A two-cylinder air-cooled horizontally opposed type engine, estimated to develop 24 h.p., was designed and built by Ray Harroun in 1910 for use in a Bleriot Type monoplane of his own design. This engine was said to weigh 95 lbs.

HARRIMAN

The Harriman Motors Company of South Glastonbury, Connecticut, designed and built their first airplane engine in 1909. Harriman engines were frequently used in pioneer flights and are claimed to have been the third successful airplane engine produced in the United States. These engines were vertical water-cooled types.

The individual cylinders were cast integrally with water-jacketed head from iron, and machined inside and out before

fitting the welded on sheet-steel jackets which surrounded the barrel. The cylinders were held in position by being screwed into the crankcase and checked with a lock nut. The valves seated in removable cages that stood vertically in the cylinder head, and were operated by an overhead camshaft and rocker arms with hardened rollers which worked upon an adjustable valve stem cap. Auxiliary exhaust ports were placed at the lower end of the cylinder to relieve the main exhaust valve.

[illegible]

The crankcases were made from aluminum, the lower half being arranged with constant level splash pockets at each crank and containing a reservoir from which the oil was forced to the main bearings by a pump. Harriman crankshafts had main bearings on each side of a crankthrow, and connecting rods of "H" section. The pistons were made from cast-iron and fitted with three wide rings.

The cooling water was circulated by an aluminum and bronze rotary pump. The inlet water header was made from aluminum and attached to the jackets by hollow bronze cap screws. Schebler carburetors and Eisemann magnetos were standard equipment.

The small Harriman engine was a four-cylinder model rated at 30 h.p. The overall dimensions were as follows: length 31.125 in., width 16.25 in., and height 24.9375 in.

A larger four-cylinder model, rated 60 h.p. at 1350 r.p.m. had a 5 in. bore and stroke, and a total displacement of 392.7 cu. in. The fuel consumption was said to be .68 lbs. per h.p-hr., and the oil consumption .037 lbs. per h.p-hr. The dry weight was reported as 240 lbs., or 4 lbs. per rated h.p. The overall dimensions were as follows: length 34.75 in., width 17.5 in., and height 28.9375 in.

Fig. 226. Inlet Side of Harriman 100-h.p. Engine.

The six-cylinder model employed at the same cylinders as the 60-h.p. engine and therefore had a total displacement of 589.05 cu. in. This engine was rated 100 h.p. at 1400 r.p.m. and reported to weigh 355 lbs., or 3.55 lbs. per rated h.p. The fuel consumption was stated to be .74 lbs. per h.p-hr. The overall dimensions were as follows: length 53.4375 in., width 17.5 in., and height 30.625 in.

HARRIS-GASSNER

The Harris-Gassner was an experimental long stroke eight-cylinder Vee type water-cooled engine built and tested by Parkins and Son of Philadelphia, Pa., during 1910. This engine was rated at 50/60 h.p., and had magneto ignition.

HART

The Hart nine-cylinder air-cooled radial engine was produced by Vickers Ltd. It was rated 156 h.p. at 1265 r.p.m., the bore being 6 in., the stroke 5 in., and the total displacement 1272.33 cu. in. The weight was reported to be 319 lbs., or 2.04 lbs. per rated h.p. The fuel consumption was stated to be .484 lbs. per h.p-hr., and the oil consumption .073 lbs. per h.p-hr. One Hart carburetor furnished the mixture. The overall diameter was 40.5 in. and the overall length 22 in.

There has also been reported a Hart nine-cylinder air-cooled rotary engine rated 150 h.p. at 1600 r.p.m. The bore was 5 in., the stroke 6 in., and the total displacement 1060.29 cu. in.

HEATH

A four-cylinder vertical water-cooled engine, rated at 30 h.p., was marketed by the Heath Aerial Vehicle Company of Chicago, Ill., during 1912 and 1913.

HENDERSON

Probably the smallest engine ever used in actual flight was the four-cylinder air-cooled Henderson motorcycle engine which developed from 5 to 6 h.p. The bore was 2.375 in., the stroke 2.1875 in., and the total displacement 38.76 cu. in. The complete weight of the engine was approximately 50 lbs. This engine was used in Harry A. Orams' machine in which Mr. Mix made flights during 1912.

HIERO

The Hiero engines were designed by Hieronimus, the well-known Austrian racing car driver. Among the early Hiero engines, produced during 1908 and 1909 by the Austrian Laurin and Klement Automobile Works, was a vertical four-cylinder 50/60-h.p. model which weighed 234 lbs. The fuel consumption was reported as .606 lbs. per h.p-hr., and the oil consumption .042 lbs. per h.p-hr. This engine had a single inlet and exhaust valve in each cylinder head operated by a common pull and push rod from a camshaft mounted in the side of the crankcase.

From 1910 to 1913 a similar four-cylinder design was produced by Werner and Pfleiderer with separate push rods to operate each valve. This engine was rated 85/95 h.p. at 1700 r.p.m., and weighed 320 lbs. The bore was 130 mm. (5.12 in.), the stroke 150 mm. (5.91 in.), and the total displacement 486.36 cu. in. The fuel consumption was reported to be .55 lbs. per h.p-hr., and the oil consumption .033 lbs. per h.p-hr.

The eight-cylinder 200/220-h.p. model was produced in 1914. This engine was reported to weigh 573 lbs., and consume .507 lbs. of fuel per h.p-hr. During the same period the first six-cylinder vertical type was built with a bore of 130 mm. (5.12 in.), a stroke of 160 mm. (6.3 in.), and a total displacement of 777.66 cu. in. This engine was rated 145 h.p. at 1400 r.p.m.

Fig. 227. The Hiero 145-h.p. Engine.

A larger six-cylinder vertical water-cooled model was built during 1915 by Essler, Warschalowski and Company of Vienna, and under license by the Loeb Motors Works of Berlin. This engine was rated normally 200 h.p. at 1400 r.p.m. The bore was 135 mm. (5.31 in.), the stroke 180 mm. (7.09 in.), and the total displacement 942 cu. in. The fuel consumption was reported to be .595 lbs. per h.p-hr., and the dry weight 695 lbs., or 3.47 lbs. per rated hp.

The individual cylinders were made of steel with welded on sheet-iron jackets. An overhead camshaft, composed of two symmetrical parts and driven by a vertical shaft from the center of the engine, was enclosed in an aluminum housing and operated single inlet and exhaust valves in each cylinder

through rocker arms. The valve timing was as follows: the inlet opened 10 degrees late and closed 35 degrees late; the exhaust opened 50 degrees early and closed 5 degrees late.

The crankshaft was supported in seven bronze bearings by caps to an aluminum crankcase. Some of these engines were made with a propeller hub on each end of the shaft to accommodate either tractor or pusher propellers; others were arranged for a starting clutch at one end.

Fig. 228. End View of Hiero 200-h.p. Engine.

The connecting rods were of "H" section and had two-bolt caps. The aluminum pistons were reinforced by cylindrical ribs, as well as star shaped ribs under the head, and fitted with four rings.

The gas mixture was furnished by two carburetors, and the ignition by two magnetos set crosswise at the center of the engine. Piston oil pumps, situated in the base chamber, were divided into two groups; the pressure group with eight cylinders, seven for the crankshaft bearings and the other for the camshaft and its vertical drive shaft, and the scavenging

Fig. 229. Intake Side of Hiero 200-h.p. Engine.

with two cylinders. The cooling water was circulated by a centrifugal pump.

A six-cylinder 230/240-h.p. model, weighing 882 lbs., was brought out in 1916. The bore was 140 mm. (5.51 in.), the stroke 180 mm. (7.09 in.), and the total displacement 1014.36 cu. in. Each cylinder had four valves in the head which were

Fig. 230. Exhaust Side of Hiero 200-h.p. Engine.

operated by an overhead camshaft driven from center. A special Schiske duplex carburetor was standard equipment.

During 1918, a six-cylinder vertical type was produced which weighed 882 lbs., and was rated 300/320 h.p. at 1400 r.p.m. The bore was 155 mm. (6.10 in.), the stroke 200 mm. (7.87 in.), and the total displacement 1380 cu. in.

By this time the output of the 200-h.p. engine had been increased to 240/250 h.p. without change in dimensions or increase in weight. This was undoubtedly accomplished by a higher compression ratio.

There were two Hiero engines developed too late during war to be put into service. One was a four-cylinder 180/190-h.p. model of 160 mm. (6.3 in.) bore and 150 mm. (5.91 in.) stroke, which was said to weigh 463 lbs. The six-cylinder 270/280-h.p. model of the same bore and stroke weighed 507 lbs.

The latest Hiero development is a two-cylinder horizontally opposed air-cooled engine rated 35/40 h.p. at 1400 r.p.m. The bore is 140 mm. (5.51 in.), the stroke 180 mm. (7.09 in.), and the total displacement 338.12 cu. in. The weight is said to be 176 lbs., and the consumption of fuel and oil .485 and .015 lbs. per h.p-hr., respectively.

HILZ

The German built Hilz airplane engines were water-cooled four-cylinder vertical types, the 45/50-h.p. model being similar in construction to the conventional automobile engine. This engine had a 120 mm. (4.72 in.) bore, 130 mm. (5.12 in.) stroke, and a total displacement of 358.36 cu. in. The weight was said to be 265 lbs.

The cylinders and pistons were of cast iron, and the crankcase of aluminum. Hilz carburetors furnished the mixture, and high-tension magnetos the ignition. A splash system of lubrication was employed, and both inlet and exhaust valves were operated directly through tappet rods.

An engine of the same dimensions and weighing 254 lbs., had an output of 50/55 h.p. In this engine the valves were situated vertically in the cylinder head, the inlet operating automatically.

Fig. 231. The Hilz 45/50-h.p. Airplane Engine.

The same design was followed in the 65-h.p. type, of 124 mm. (4.88 in.) bore, 140 mm. (5.51 in.) stroke, and 413 cu. in. total displacement.

HISPANO-SUIZA

The Societe Hispano-Suiza presented the first Hispano-Suiza airplane engine in the spring of 1916. The French military authorities adopted the type and they were installed in Spad airplanes during August, 1916, and sent to the front, where their value as fighting engines was convincingly demonstrated. The early success of the Hispano-Suiza engine led to the development of other types, but the facilities were not sufficient to produce the numbers required. Other French firms, as well as the Wolseley Motors Limited in England, and the Simplex Automobile Company in America, were given manufacturing rights.

The Hispano-Suiza engines were adapted to American manufacturing methods and produced in quantities by the Wright-Martin Aircraft Corporation of New Brunswick, New Jersey, a firm newly organized for that purpose. The U. S. Government subsidized the building of a plant at Long Island City for the production of the Model H engine, which was a copy of one of the later French designs that had been developed in order to meet the higher power requirements.

After the signing of the Armistice the firm was renamed the Wright Aeronautical Corporation and shortly moved to the plant in Paterson, New Jersey, which they now occupy. The engines produced by the new organization were for a time known as the Wright-Hispano's, but more recently they have been called the Wright engines. The firm claims that the improvements effected during the development work carried on by them warrants the engine being recognized as an American product.

All Hispano-Suiza engines are licensed under the Birkigt patents which cover a number of design features that are quite vital to the engine as a whole. The same general form of construction is common to all types.

The cylinders are formed from an aluminum block casting with cored water passages into which are screwed four forged steel barrels that are threaded on the outside, closed at the top, and provided with a mounting flange at the bottom. Gas passages are formed in the aluminum, and the valves seat on the steel head. The assembly is coated with baked enamel both inside and out.

The pistons are made from aluminum castings and fitted with four narrow rings placed in two grooves at the top, and a lower oil scraper ring that has a relief cut just below it. The connecting rods are of the forked type and have tubular sections. The forked rod is generally held with four bolts to a two-piece bronze box that bears on the crankpin. The central rod then bears on the outer portion of the bronze box and has its cap held in place by two bolts. The crankshaft is a conventional four-throw five-bearing type with four plain babbitt lined bronze bearings, a single-row radial ball bearing at the timing end, and a double-row ball thrust type at the propeller end.

One of the principal features of the Hispano-Suiza design is the valve gear. The valves seat vertically in the cylinder head along the center of each block and are operated directly from a single super-imposed camshaft. The valve stems are of large diameter and hollow, and are provided at the upper end with an adjustable disc upon which a wide faced mushroom type cam operates. This disc has a threaded boss which

screws into the valve stem, and serrations on its under side matching with similar serrations on another disc that retains the two concentric helical valve springs. Adjustments are easily made by a special wrench which fits into one of the holes on the rim of the lower disc and lowers it sufficiently, in turning the upper disc by the notches on its rim, for disengagement of the serrations. Each camshaft is supported by three plain bronze bearings and driven by a vertical driveshaft and bevel gears. The valve mechanism is enclosed by an oil tight cover.

The cooling water is circulated by a centrifugal pump, and the lubricating oil by gear pumps. Dual ignition is supplied by magnetos, the Dixie "800" type being used entirely on the American built engines. Duplex carburetors are situated in the Vee.

Fig. 232. The Model D Hispano-Suiza Engine.

Model A. The first Hispano-Suiza engines were water-cooled eight-cylinder 90 degree Vee types, rated 150 h.p. at 1450 r.p.m. The bore was 120 mm. (4.72 in.), the stroke 130 mm. (5.12 in.), and the total displacement 718.88 cu. in. The compression ratio was 4.72 to 1.

The fuel consumption is reported as .55 lbs. per h.p-hr., and the oil consumption as .039 lbs. per h.p-hr. The Model A

engine is often used without an oil radiator. The Wright-Martin built engines were fitted with Stromberg NA-D4, or Twin type Zenith carburetors.

The clear diameter of the valves is 50 mm. (1.968 in.) and the lift is 10 mm. (.394 in.). The valve timing is as follows: the inlet opens 10 degrees late and closes 50 degrees late; the exhaust opens 45 degrees early and closes 10 degrees late.

Fig. 233. Magneto End of Hispano-Suiza Models E and I.

The overall dimensions of the Model A are as follows: length over propeller hub and starting crank 56.69 in., and from the inside of the propeller hub to the end of the magnetos 42.66 in., width 33.4375 in., and height 32.75 in. The dry weight is approximately 445 lbs., or 2.96 lbs. per rated h.p.

The magnetos are mounted in the plane of the cylinders on extensions of the upper half crankcase and driven by bevel gears from the vertical drive shafts. In the Model A engines, the center connecting rod holds the split bronze bearing and the forked rod bears upon its outer surface. The wrist pin is locked in the piston, a practice discontinued on some of the later types.

Model B. The Model B Hispano-Suiza engine is a four-cylinder vertical type that uses one Model A cylinder block. This engine is rated 75 h.p. at 1450 r.p.m., and is reported to weigh 315 lbs., or 4.2 lbs. per rated h.p.

Model C. The Model C Hispano-Suiza engine is rated at 200 h.p. This is in reality a Model A operating normally at a higher speed and employing a geared down propeller drive. The propeller shaft extends the entire length of the engine in the Vee with the driving gears located at the anti-propeller end.

Model D. The Model D Hispano-Suiza engine, which is also rated at 200 h.p., employs propeller reduction gears at the propeller end of the engine. A gun, mounted in the Vee, can be fired through the short hollow propeller shaft.

Fig. 234. Propeller End of Hispano-Suiza Models E and I.

Model E. The Model E, rated at 180 h.p., is in reality a Model I engine operating at a higher normal speed and using a compression ratio of 5.33 instead of 4.72. A larger carburetor is installed to take care of the increased volume of mixture, and the magneto advance is increased from 20 degrees 20 minutes to 25 degrees in order to obtain the best results at the higher operating speeds.

The horsepower developed at 1700 r.p.m. is 185, and at 1800 r.p.m. it is 190. At 2200 r.p.m. about 220 h.p. is developed. The weight is ordinarily the same as the Model I, therefore the E type weighs 2.61 lbs. per rated h.p. The fuel consumption ranges from .49 to .52 lbs. per h.p-hr., and the oil consumption should never exceed .02 lbs. per h.p-hr. At 1600 r.p.m., 117 lbs. per sq. in. b.m.e.p. is the maximum developed.

Fig. 235. Side View of Hispano-Suiza Models E and I.

Model E-2. The Model E-2 is a Model E high compression engine with the following improvements incorporated: the steel cylinder head has been made heavier with a view of reducing valve troubles; the magnetos are located in a more accessible position on inclined brackets at the rear end of the engine; a triple-geared oil pump replaces the old design; and a front oil drain is provided for the camshaft cover. Also the lower half crankcase is made shallower, and the adjustment for camshaft timing is provided on the vertical drive shaft.

Model F. The Hispano-Suiza Model F engine is similar to the Model D except that no provision is made for mounting a gun in the Vee.

Model H. The Model H Hispano-Suiza engine is frequently referred to as the 300-h.p. Model. This is a water-cooled eight-cylinder 90 degree Vee type, employing the same

form of construction as the smaller models. The bore is 140 mm. (5.51 in.), the stroke 150 mm. (5.91 in.), and the total displacement 1127.36 cu. in.

The Model H normally develops 325 h.p. at 1800 r.p.m. and its dry weight is 632 lbs., or 1.94 lbs. per rated h.p. The compression ratio is 5.32. The maximum horsepower developed at 2200 r.p.m. is 375 and the maximum brake mean effective pressure which occurs at 1850 r.p.m. is 127 lbs. per sq. in. The consumption of fuel and oil at normal power are, respectively, .521 and .055 lbs. per h.p-hr.

The inlet and exhaust valves each have a clear diameter of 56 mm. (2.205 in.), a lift of 13 mm. (.511 in.), and 45 degree seats. The timing of the valves is as follows: the inlet opens 10 degrees early and closes 62 degrees late; the exhaust opens 62.5 degrees early and closes 29.5 degrees late.

Fig. 236 Transverse Section and End View of Hispano-Suiza Model H.

Fig. 237. Section of Model H 300-h.p. Hispano-Suiza Engine.

Model H-2. The Model H-2 is a Model H with improvements. Inclined magneto brackets are substituted for the cross-wise drive.

Model I. The Model I engine corresponds to the Model A in dimensions and rated output. The position of the magnetos has been improved by placing them cross-wise, and the connecting rods are of a later design common to most Hispano-Suiza engines. The weight is reported as 470 lbs., or 3.13 lbs. per rated h.p.

Model K. The Model K is a geared 300-h.p. engine designed to carry a 37 mm. full automatic cannon in the Vee. The crankcase is jointed along the vertical center line.

The re-designed Model K-2 engine has the halves of the crankcase joined along the horizontal centerline according to conventional practice. The propeller shaft gear housing cover is removable, and a triple-geared oil pump, the same as used on the Model E-2, is fitted.

Model M. The Model M is an experimental 300-h.p. engine using built-up and welded steel cylinder construction and a valve gear design patterned after the Liberty.

French Experimental Types. The original 300-h.p. engine, which was later known in France as the Model 42 and in America as the Model H, had a 140 mm. (5.51 in.) bore and stroke. The stroke was later changed to 150 mm. (5.91 in.). Both direct and geared propeller drive engines were built; the direct drive engine was rated 300 h.p. at 1800 r.p.m., and the geared type 320 h.p. at 2000 r.p.m. The former was reported to weigh 528 lbs., or 1.76 lbs. per rated h.p., and the geared engine 605 lbs., or 1.89 lbs. per rated h.p.

Fig. 238. Rear End of Model H Hispano-Suiza Engine.

Sixteen-cylinder Vee types were also built experimentally. An engine formed from four Model A cylinder blocks of 120 mm. (4.72 in.) bore, 130 mm. (5.12 in.) stroke, and with a total displacement of 1437.76 cu. in., was rated at 400 h.p. at 2000 r. p.m. The propeller speed could be reduced either .6 or .75 that of the crankshaft. The weight was reported to be 1045 lbs., or 2.61 lbs. per rated h.p.

A sixteen-cylinder Vee type using the Model 42 cylinder blocks of 140 mm. (5.51 in.) bore and 150 mm. (5.91 in.)

stroke, had a total displacement of 2254.72 cu. in. This engine was rated 600 h.p. at 2000 r.p.m., and said to weigh 1210 lbs., or 2.01 lbs. per rated h.p. Propeller reduction gears, having the same ratios of the smaller sixteen-cylinder model, were employed.

Fig. 239. Side View of Model H Hispano-Suiza Engine.

HODGE

The G. O. Hodge air-cooled rotary engine was built experimentally by the New Britain Machine Company of New Britain, Connecticut, during the war. This engine had eighteen cylinders in two rows of nine at alternate positions, the bore and stroke being 4 in., and the total displacement 904.68 cu. in. At 2000 r.p.m., the sum of the revolutions of the cylinders and crankshaft, the engine was rated 320 h.p. The compression ratio was 5 to 1.

The cylinders were constructed of steel with aluminum heads. There were two exhaust valves of 1.375 in. diameter and one inlet valve of 1.75 in. diameter, all of which lifted .375 in. and employed 45 degree seats. The stationary cam mechanism was composed of three groups of cams, two in a group. Simultaneous with the firing of a cylinder in one row, another cylinder fired diametrically opposite in the second

row. The valve timing was as follows: the inlet opened 10 degrees late and closed 35 degrees late; the exhaust opened 40 degrees early and closed 5 degrees late.

The connecting rods had "H" sections, and the pistons were made of Magnalite. Zenith carburetors supplied the mixture, and forced-feed lubrication with 7 lbs. pressure was employed. Ignition was by three Bosch two-spark magnetos. The weight was estimated at 480 lbs., or 1.5 lbs. per rated h.p. The outside diameter was 34 in. and the overall length 44 in.

HOFER

A four-cylinder vertical air-cooled engine, rated 10 h.p. at 1200 r.p.m., was designed and built by Al. Hofer at Chicago during 1910. This engine was flown by Laird in 1913 in a machine which he built through the assistance of Mr. Hofer, and which he used in exhibition flights successfully for quite a period following.

Fig. 240. Longitudinal Section of Hudson Radial Engine.

The bore was 3.125 in., the stroke 3.75 in., and the total displacement 115.04 cu. in. The compression ratio was 3 to 1, and the engine was said to weigh 120 lbs., or 12 lbs. per rated h.p.

The cylinders with integral cooling fins were made from cast iron. The valves were located in the cylinder head, and auxiliary exhaust ports were provided in the lower part of the cylinder barrel. The inlet and exhaust valves were each of 1.5 in. diameter, and had 45 degree seats and a lift of .3125 in. The valve timing was as follows: the inlet opened on top center and closed from 15 to 20 degrees late; the exhaust opened on bottom center and closed on top center.

Lubrication was by splash with a pump to circulate the oil. A motorcycle type carburetor was used, and an Eiseman high-tension magneto furnished the ignition. The crankshaft and connecting rods were drop forged from carbon steel, and the pistons were made from cast iron.

HOLBROOK

The Holbrook was a 35-h.p. engine built during 1910. The engine was tested out in a machine built by Mr. H. J. French.

HOWARD

The Howard was a six-cylinder vertical water-cooled engine, rated 120 h.p. at 2020 r.p.m., with the propeller speed reduced to approximately one-half that of the crankshaft. The bore was 150 mm. (5.91 in.), the stroke 105 mm. (4.13 in.), and the total displacement 679.8 cu. in.

One Zenith carburetor furnished the mixture, and a rotary pump circulated the oil. The fuel consumption was reported to be .482 lbs. per h.p-hr., and the oil consumption .055 lbs. per h.p-hr. Magneto ignition was employed. The approximate overall dimensions were as follows: length 60 in., width 21.25 in., and height 37 in.

HUDSON

The ten-cylinder air-cooled radial engine, designed and built by John W. Hudson, had a normal rating of 100 h.p. at 1000 r.p.m., and 120 h.p. at 1200 r.p.m. The bore was 4.3125

in., the stroke 4.75 in., and the total displacement 693.8 cu. in. The weight was said to be 320 lbs., or 3.2 lbs. per rated h.p.

The cylinders, with integral circumferential cooling flanges, were made from steel; the valve ports were attached to the cylinder head, and cast-iron cylinder liners pressed into place. The pistons were of cast iron and employed an obturator ring. The wrist pin was locked in the piston, the bearing in the upper end of the connecting rod being directly lubricated from the crankpin through an oil tube clipped onto the rod. The connecting rods were of the articulated type and had "H" sections, each rod assembly being mounted on two annular ball bearings.

The two-throw crankshaft was counterbalanced and also supported on ball bearings. The crankcase was of built-up steel construction, the rear end enclosing the cam mechanism, and the front end a number of aluminum coils around which the gas must pass after passing through the crank chamber and before entering the inlet pipes. Two magnetos, one in an upright and the other in an inverted position, were mounted just back of the propeller hub and driven directly through gears.

Fig. 241. The Eight-Cylinder Indian Engine.

INDIAN

The Hendee Mfg. Company of Springfield, Mass., well known as the manufacturer of Indian motorcycles, was at one time engaged in building two types of airplane engines; one an eight-cylinder water-cooled Vee type and the other a seven-cylinder air-cooled rotary.

The eight-cylinder engine was used by Curtiss in long distance flights at the Harvard Aviation Meet. It had a 4 in. bore, 4.5 in. stroke, 452.4 cu. in. total displacement, and was rated from 60 to 65 h.p. This engine was equipped with magneto ignition, and reported to weigh 260 lbs.

The cylinders had separate "L" shaped heads and were fitted with brass water jackets. An inlet valve, situated directly above the exhaust, was operated by a push rod and rocker arm. It was carried in a cage that could be removed

Fig. 242. Elevation of Indian Air-Cooled Rotary Engine.

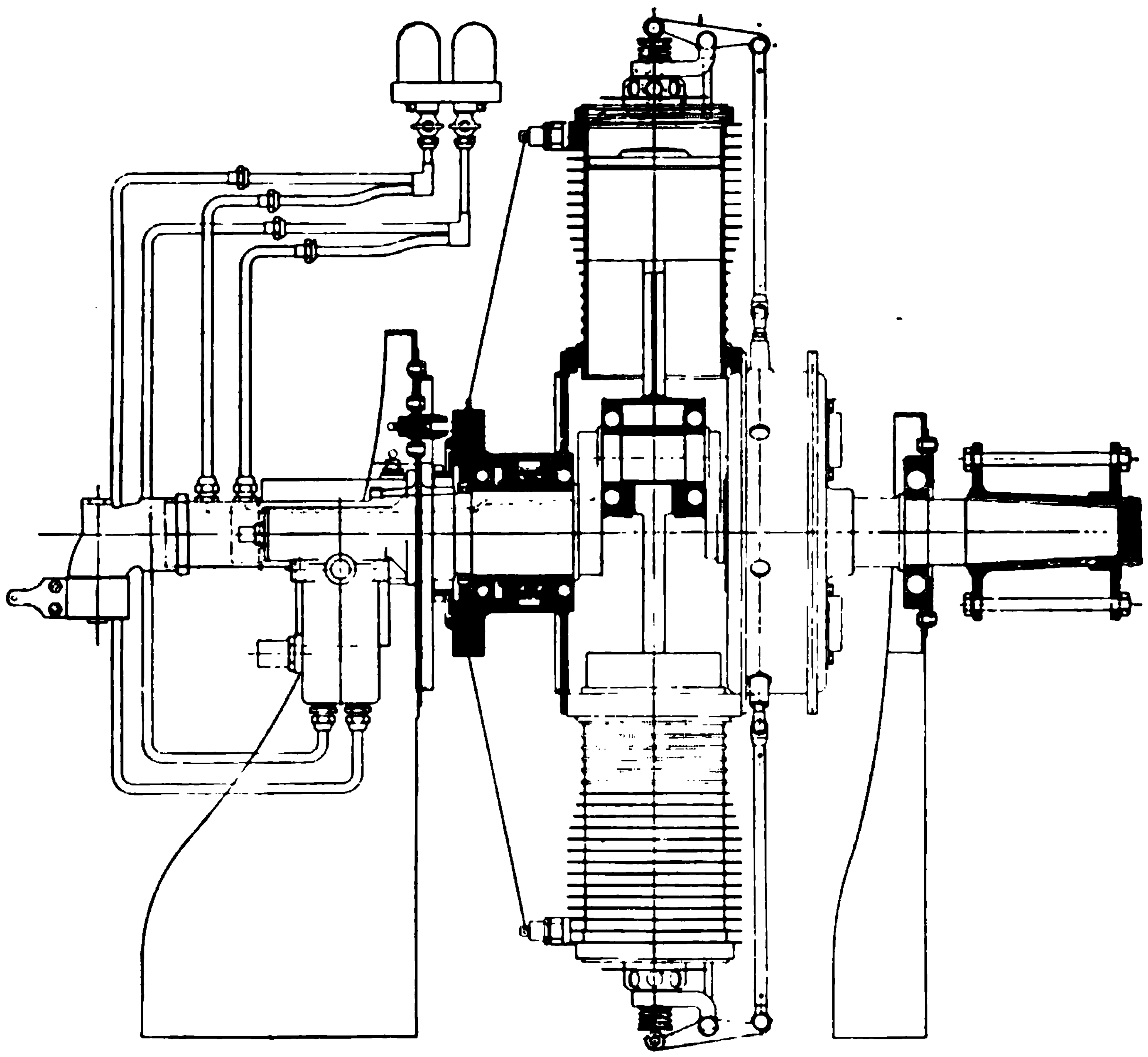


Fig. 243. Longitudinal Section of Indian Rotary Engine.

to permit the removal of the exhaust valve which was operated directly from the cam shaft through tappets.

The seven-cylinder air-cooled rotary engine was rated 50 h.p. at 1100 r.p.m. The bore was 4.375 in., the stroke 4.875 in., and the total displacement 513 cu. in. The engine was said to weigh 185 lbs., or 3.7 lbs. per rated h.p., and measure 36 in. in overall diameter.

This engine was constructed largely of nickel steel, and ball bearings were used throughout. Magneto ignition was provided, and the lubricating oil was forced by pumps through sight feed oilers before going to the main bearings. The inlet valves were situated in the piston head and operated automatically, while the mechanically operated exhaust valves used very light springs as centrifugal force was depended upon for holding them on their seats during running. The cylinder head, in which the exhaust valve seated, could be removed by unscrewing a castellated ring.

INTERNATIONAL

The International engines, built in 1909, were unconventional air-cooled rotary types; the cylinders being even in number.

The smaller, a four-cylinder engine, was rated 21.5 h.p. at 1500 r.p.m. The bore was 95 mm. (3.74 in.), the stroke 64 mm. (2.52 in.), and the total displacement 110.72 cu. in. The weight was stated to be 80 lbs., or 3.72 lbs. per rated h.p.

The six-cylinder model was rated 66 h.p. at 1500 r.p.m. and reported to weigh 130 lbs., or 1.9 lbs. per rated h.p. The bore was 127 mm. (5 in.), the stroke 101 mm. (3.98 in.), and the total displacement 468.9 cu. in.

ISAACSON

The Isaacson engines were British built air-cooled types appearing in both rotary and radial form. The two rotaries, of 120 mm. (4.72 in.) bore and 150 mm. (5.91 in.) stroke, were nine and eighteen-cylinder engines with inlet valves located in the pistons and exhaust valves in the cylinder heads.

The nine-cylinder model, of 930.69 cu. in. total displacement, was rated 100 h.p. at 1200 r.p.m.; and was stated to weigh 250 lbs., or 2.5 lbs. per rated h.p.

Fig. 244. The Isaacson Eighteen-Cylinder Rotary Engine.

The eighteen-cylinder engine, of 1861.38 cu. in. total displacement, was rated 200 h.p. at 1200 r.p.m.; and was said to weigh 465 lbs., or 2.33 lbs. per rated h.p.

The smaller of the air-cooled radial forms was a seven-cylinder engine, rated 50 h.p. at 1600 r.p.m. The bore was 90 mm. (3.54 in.), the stroke 115 mm. (4.53 in.), and the total displacement 312.06 cu. in. The propeller was mounted so as to run one-half crankshaft speed. The crankshaft was mounted on ball bearings, and the pistons were made of steel. Bosch magnetos supplied the ignition. The total weight was reported to be 195 lbs., or 3.9 lbs. per rated h.p.

A fourteen-cylinder air-cooled radial engine, rated 100 h.p. at 1600 r.p.m., was a double form of the seven-cylinder model and had a total displacement of 624.12 cu. in. The dry weight was reported to be 290 lbs., or 2.9 lbs. per rated h.p.

An Isaacson seven-cylinder air-cooled radial engine, rated 65 h.p. at 1100 r.p.m., had a 110 mm. (4.33 in.) bore, 130 mm. (5.12 in.) stroke, and a total displacement of 527.73 cu. in. This engine employed an inlet valve in the piston and an exhaust valve in the cylinder head in the same manner as the air-cooled rotary types. The dry weight was stated to be 196 lbs., or 3 lbs. per rated h.p.

ISOTTA-FRASCHINI

The Isotta-Fraschini Company, well-known Italian automobile manufacturers with factories in Milan, began the study of airplane engines some time before the war and built a few experimental types which gave very promising results. When Italy entered the war, this firm turned its efforts entirely to airplane engine construction. Other firms were also licensed to build certain Isotta-Fraschini types; the V-4-B and V-6 models being constructed by the Eduardo Bianchi Co., and the V-6 model also by San Giorgio of Sestri Ponente and Romeo of Milan.

V-4-B. A widely used Isotta-Fraschini model was the V-4-B, a six-cylinder vertical water-cooled engine rated 170 h.p. at 1450 r.p.m. The bore was 130 mm. (5.12 in.), the stroke 180 mm. (7.09 in.), and the total displacement 875.22

cu. in. This engine was arranged for a direct driven propeller, and employed a compression ratio of 5 to 1. The weight was reported to be 605 lbs., or 3.56 lbs. per rated h.p.

The mixture was supplied by two Zenith carburetors having 36 mm. chokes, 1.55 mm. main jets, and from 1.4 to 1.5 mm. compensator jets. Force feed lubrication was provided by a gear pump. The fuel consumption was stated to be .485 lbs. per h.p-hr., and the oil consumption .033 lbs. per h.p-hr.

Fig. 245. The Isotta-Fraschini Type V-4-B Engine.

The cylinders were made up in pairs from cast iron and fitted with either steel or copper water jackets. The overhead camshaft was provided with a compression release gear. The inlet valve seated in a cage and the exhaust in the cylinder head, each pair of valves having a single spring with a pivoted rocker arm.

The crankshaft was a six-throw four-bearing type supported by separate bearing caps with four bolts each. The connecting rods were of tubular section and employed two-bolt caps. The aluminum pistons were ribbed underneath the head, and dual ignition was furnished by two six-cylinder Marelli magnetos.

V-5. An eight-cylinder vertical water-cooled engine, using the same cylinders as the V-4-B model and therefore

having a total displacement of 1166.96 cu. in., was rated 200 h.p. at 1400 r.p.m. The eight-throw crankshaft was supported in five plain bearings. Two carburetors furnished the mixture, and a force feed system of lubrication was used. Dual ignition was provided by two eight-cylinder magnetos. The total weight was reported to be 825 lbs., or 4.12 lbs. per rated h.p.

There has also been reported an Isotta-Fraschini engine similar to the V-5 model but having a 190 mm. (7.48 in.) stroke. The total displacement of this engine would be 1231.12 cu. in.

Fig. 246. The Isotta-Fraschini Type V-5 Engine.

V-6. The Isotta-Fraschini V-6 type is a six-cylinder vertical water-cooled engine, rated 250 h.p. at 1650 r.p.m. and said to develop about 275 h.p. at a maximum speed of 1800 r.p.m. The bore is 140 mm. (5.51 in.), the stroke 180 mm. (7.09 in.), and the total displacement 1014.36 cu. in. The compression ratio is 5.1.

The fuel consumption ranges from .485 lbs. to .503 lbs. per h.p-hr., and the oil consumption from .033 lbs. to .043 lbs. per h.p-hr. Two Zenith carburetors feed three cylinders each. Lubrication is of the dry sump type, a triple vane pump turning at 1.25 times engine speed being employed; the upper unit supplies pressure oil to the bearings, and the two lower units are used for scavenging purposes. There is an overflow oil pipe from the camshaft housing located at the propeller end.

The steel cylinders are machined separately and then arranged in pairs. A bolted on aluminum casting, which contains the inlet and exhaust valve ports, forms the head for each pair of cylinders. Steel water jackets are held in place by a number of small screws. The valves stand vertically in the cylinder head and are operated from an enclosed overhead camshaft that is mounted in seven plain bearings. The camshaft acts upon interposing levers instead of directly upon the valves. The adjustment provided for setting the valve clearance is quite similar in design to that used on Hispano-Suiza engines. One inlet and one exhaust valve per cylinder are each of 60 mm. (2.36 in.) clear diameter and have 30 degree seats, the inlet valve lifting .433 in. and the exhaust valve .4921 in. The valve timing is as follows: the inlet opens 8 degrees late and closes 48 degrees late; the exhaust opens 40 degrees early and closes 14 degrees late.

Fig. 247. Transverse Section of Isotta-Fraschini V-6 Engine.

The crankshaft is a four-bearing type, and the connecting rods have been built with both "H" and tubular sections. The aluminum pistons are ribbed on the interior and fitted with four rings, the lower of which acts as an oil scraper. Dual ignition is furnished by two Marelli EM-6 magnetos. The total dry weight is reported to be 620 lbs., or 2.48 lbs. per rated h.p. The approximate overall dimensions are as follows: length over propeller hub 68 in., width 20 in., and height 39.5 in.

V-7. A twelve-cylinder 60 degree Vee type engine, of the same bore and stroke as the V-6 model and having a total

Fig. 248. The Isotta-Fraschini Type V-6 Engine.

piston displacement of 2028.72 cu. in., is rated at 400 h.p. and said to actually develop 460 h.p. at a normal speed of 1500 r.p.m. and 510 h.p. at 1700 r.p.m. The dry weight is reported to be 1070 lbs., or 2.67 lbs. per rated h.p.

The lubricating system is the same as in the V-6 type. The mixture is furnished by four Zenith carburetors which feed three cylinders each, and dual ignition is furnished by four magnetos. The fuel consumption is reported to be .485 lbs. per h.p-hr., and the oil consumption .033 lbs. per h.p-hr.

V-8. The Isotta-Fraschini V-8 type, an engine derived from the V-6 model, is rated 300 h.p. at 1800 r.p.m.; the bore being 150 mm. (5.91 in.), the stroke 170 mm. (6.69 in.), and the total displacement 1101.12 cu. in. This engine employs a six-throw seven-bearing crankshaft, and has separate steel cylin-

Fig. 249. The Isotta-Fraschini Type V-7 Engine.

ders with sheet-iron water jackets which are both welded and fastened in place by screws. The dry weight is reported to be 595 lbs., or 1.98 lbs. per rated h.p.

Fig. 250. The Isotta-Fraschini Type V-9 Engine.

V-9. The V-9 engine is claimed to be more strongly built than any of the former Isotta-Fraschini models. It is a six-cylinder vertical water-cooled engine of 150 mm. (5.91 in.) bore, 180 mm. (7.09 in.) stroke, and 1167 cu. in. total displacement, rated 310 h.p. at 1700 r.p.m. The cylinders are of individual steel construction similar in design to those of the V-8 model. The total dry weight is reported as 684 lbs., or 2.2 lbs. per rated h.p.

JAENSON

The Jaenson was an experimental French engine with eight cylinders in 90 degree Vee formation. The bore was 150 mm. (5.91 in.), the stroke 200 mm. (7.87 in.), and the total displacement 1727.12 cu. in. This engine was water-cooled, and arranged for a direct driven propeller. Normally rated at 300 h.p., the output was reported to actually reach 360 h.p. at 1450 r.p.m. and 400 h.p. at 1680 r.p.m. The dry weight was said to be 780 lbs., or 2.6 lbs. per rated h.p.

J. A. P.

The eight-cylinder Vee type J. A. P. engines were built in England during 1909 and 1910. The smaller model was air-cooled and the larger one water-cooled.

The air-cooled engine was rated 38 h.p. at 1500 r.p.m. and weighed 220 lbs., or 5.8 lbs. per rated h.p. The bore was 85 mm. (3.35 in.), the stroke 95 mm. (3.74 in.), and the total displacement 263.68 cu. in.

The water-cooled engine was rated 45 h.p. at 1300 r.p.m. and weighed (dry) 303 lbs., or 6.75 lbs. per rated h.p. The bore was 90 mm. (3.54 in.), the stroke 110 mm. (4.33 in.), and the total displacement 340.88 cu. in.

J. A. P. 9-h.p. twin motorcycle engines were used by A. V. Roe in a number of his early flights.

JOHNSON

The two-cycle water-cooled Johnson engines, which were built in America, appeared with six, eight, and twelve cylinders arranged in 90 degree Vee form, and had a bore of 5 in. and a stroke of 4 in.

The six-cylinder model, which had a total displacement of 471.24 cu. in., was rated 75 h.p. at 1300 r.p.m. The dry weight was stated to be 298 lbs., or 3.97 lbs. per rated h.p. Including the cooling system, the weight was reported as 379 lbs.

The eight-cylinder model, which had a total displacement of 628.32 cu. in., was rated 100 h.p. at 1300 r.p.m. This engine was reported to weigh (dry) 418 lbs., or 4.18 lbs. per rated h.p.; the weight including the cooling system being 508 lbs.

The twelve-cylinder design was rated 150 h.p. at 1300 r.p.m. This engine had a total displacement of 942.48 cu. in. and was reported to weigh (dry) 598 lbs., or 3.98 lbs. per rated h.p. With cooling system the engine was said to weigh 728 lbs.

JUNKERS

Prof. Junkers of Aachen, Germany, experimentally built two-stroke Diesel type airplane engines during the war. As in the stationary types, there were separate crankshafts at each side; the two shafts being connected together at one end by a train of spur gears, with the central gear arranged to drive a propeller.

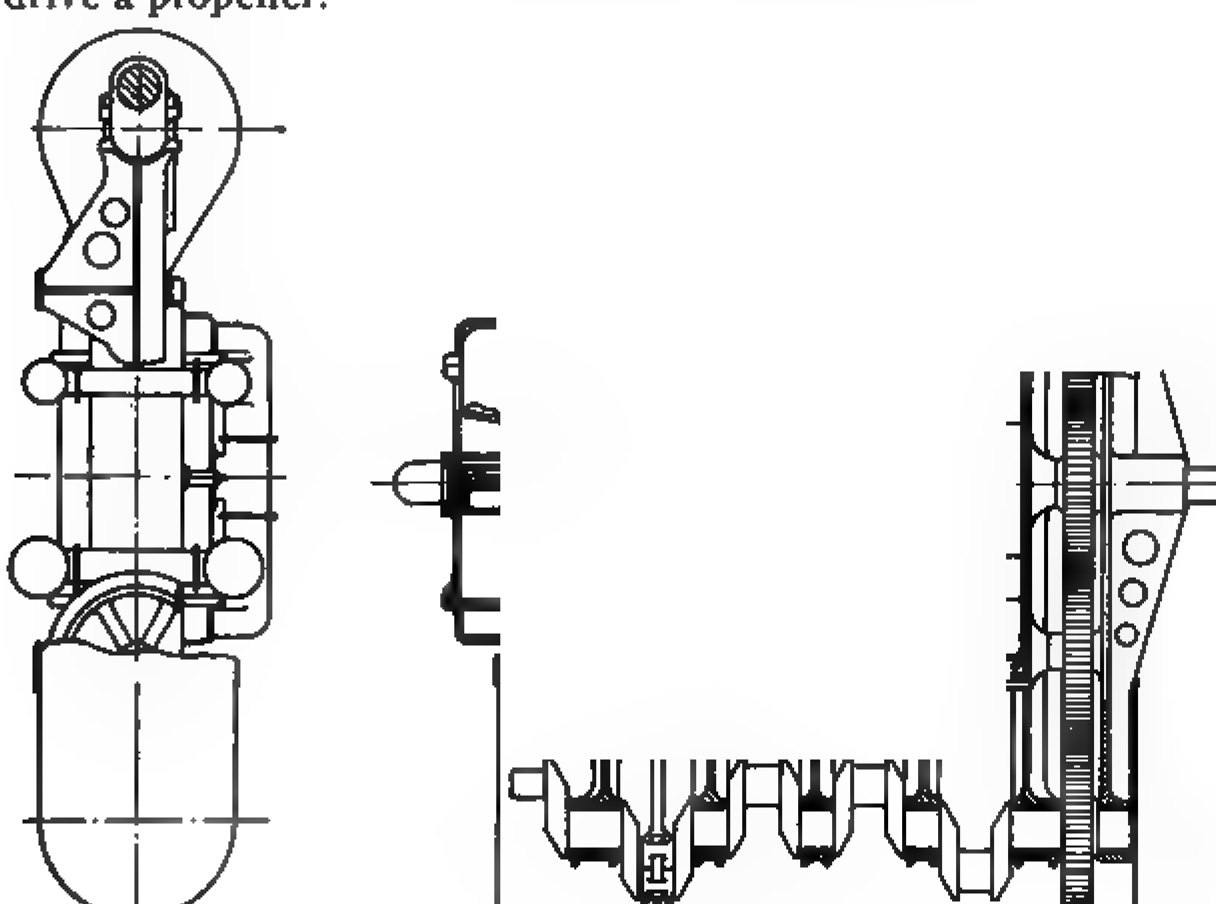


Fig. 251. Diagram of Junkers Airplane Engine.

Two pistons, working in opposite directions in each cylinder, uncovered inlet and exhaust ports near the end of their stroke. The exhaust port was uncovered first, and when the inlet port was uncovered, a compressed charge of air was forced through the cylinder by a pump, thereby practically clearing it of all burnt gases. Due to the excellent scavenging, perfect inertia balance, and absence of restricted valve area, it appears possible that Diesel engines of this type may be made to run at high speed and develop high mean effective pressures.

The cooling system was reported to be effective. The working surfaces of the cylinder were completely surrounded by cooling water, and the piston contained a cooling fluid that was said to greatly assist in the transmission of the heat from the head to the skirt where it was given up to the cylinder walls.

A four-cylinder engine, developed in the Laboratories of Prof. Junkers, was said to develop 200 h.p. at 1000 r.p.m. and weigh about 3.5 lbs. per h.p. The overall dimensions were as follows: length 52 in., width 61 in., and height 18 in. A six-cylinder engine is also said to have been built experimentally.

KELLY

The Kelly was a British built two-cycle four-cylinder vertical water-cooled engine, rated at 200 h.p. The bore was 165.1 mm. (6.5 in.), the stroke 160 mm. (6.3 in.), and the total displacement 836.2 cu. in. Magneto ignition was employed, and two Schebler carburetors furnished the mixture. Two oil pumps were used, one being a plunger type and the other a rotary. The approximate overall dimensions were as follows: length 63 in., width 20 in., and height 32.5 in.

KEMP

The Kemp Machine Works of Muncie, Indiana, have built several types of air-cooled engines for airplanes and as air-drives for boats, motorcycles, and ice boats.

1-4. The Kemp Model I-4 is a four-cylinder vertical engine of 4.25 in. bore, 4.5 in. stroke, and 255.36 cu. in. total displacement, rated 35 h.p. at 1150 r.p.m. This engine weighs (completely equipped) 192 lbs., or 5.48 lbs. per rated h.p.; and

is erroneously reported to consume 13.8 lbs. of gasoline and 3.75 lbs. of oil per hr.

The cylinders are cast from iron. The valves stand vertically in the cylinder head, the inlet being operated automatically and the exhaust by push rods and rockers. The crankshaft is a five-bearing type, the connecting rods have "H" sections, and cast-iron pistons with ribs under the head are each fitted with two rings. Lubrication is of the splash type; the oil is pumped from a sump in the under pan to compartments in the case which are separated by baffle plates in order to maintain a level of sufficient depth for the connecting rods to dip. The crankshaft is fitted with two sets of thrust bearings to provide for thrust loads in either direction. Schebler carburetors and Mea magnetos are supplied as standard equipment.

Fig. 252. The Kemp Model I-4 Engine.

H-6. A six-cylinder model of the same bore and stroke, which closely follows the Model I-4 in design, is rated 55 h.p at 1150 r.p.m. The total displacement is 383.04 cu. in. and the weight (completely equipped) is said to be 272 lbs., or 4.94 lbs. per rated h.p. This engine is erroneously reported to consume 21 lbs. of gasoline and 4.68 lbs. of oil per hr. The H-6 model employs a seven-bearing crankshaft.

J-8. An eight-cylinder air-cooled Vee type, known as Model J-8, is rated 80 h.p. at 1150 r.p.m. The bore is 4.25 in.,

Fig. 253. The Kemp Model H-6 Engine.

the stroke 4.75 in., and the total displacement 539.04 cu. in. This engine is erroneously reported to consume 26.4 lbs. of gasoline and 6.56 lbs. of oil per hr.; and is said to weigh 380 lbs., or 4.33 lbs. per rated h.p.

The crankshaft has five plain bearings. The connecting rods have "H" sections, with a third rib in the center, and are made from aluminum bronze. The positive forced draft cooling system consists of a fan, mounted on the crankshaft just

Fig. 254. The Kemp Model J-8 Engine.

back of the propeller hub, which discharges air into the two manifolds leading to jackets that partially surround the cylinders. The BH-8 Mea magneto is the standard ignition equipment, and Zenith or Model L Schebler carburetors are furnished as desired.

KESSLER

During the war, the Army and Navy were jointly interested in the development of a six-cylinder vertical water-cooled supercharged engine that was being designed and built by the Kessler Motor Co. of Detroit, Michigan. This engine operated on the ordinary four-stroke cycle, but at the bottom

Fig. 255. The Kessler 200-h.p. Supercharged Engine.

of the intake stroke the piston uncovered ports through which a quantity of air was forced under pressure into the combustion chamber. It was claimed that with this added volume of air it was possible to economically use, under normal operating conditions, a compression ratio as low as 3.66 to 1. The pressure was created by crankcase compression, the quantity of air admitted to the cylinders being governed by a rotary valve between the crankcase and cylinder intake port. This valve was connected with the throttle so as to automatically govern the amount of air admitted during throttled conditions.

The cylinders and water jackets were cast en bloc. A single overhead camshaft operated four valves in each cylinder through off-set vee-shaped rocker arms, which were

pivoted on either side and employed a mushroom type of follower. The camshaft was driven through a train of spur gears. The crankshaft was counterbalanced, and the connecting rods had "H" sections and two-bolt caps. The pistons were of unusual design, the sides being entirely opened up at the center except for that portion required for thrust purposes.

Fig. 256. The 6C-400 Kessler Engine.

A Kessler engine, rated 200 h.p. at 2400 r.p.m., had a bore of 4.75 in., a stroke of 5 in., and a total displacement of 531.63 cu. in. This engine employed propeller reduction gears.

Experiments were also made with a six-valve engine known as the Model 6C-400. This engine was said to weigh 578 lbs., the bore being 5.5 in., the stroke 6 in., and the total displacement 855.3 cu. in.

KING

During the war, the Aircraft Board authorized the building and testing of five engines designed by Chas. B. King. The work on these engines was started at the plant of Brewster and Co., Long Island, N. Y., immediately following Mr. King's supervision of the King-Bugatti designs. At the sign-

ing of the Armistice all work was stopped, and the engine parts then completed were shipped to McCook Field, Dayton, Ohio. The King engine was designed for installation in airplanes equipped with the twelve-cylinder Liberty, being claimed that it would offer less head resistance, occupy less space, and develop a greater power output.

The King .engine had twelve water-cooled cylinders arranged in two rows of six at 45 degrees. The bore was 5.5 in., the stroke 7 in., and the total displacement 1995 cu. in. The estimated horsepower was 550 at 1886 r.p.m. (engine) and at 1300 r.p.m. (propeller). The compression ratio was 5 to 1. The estimated dry weight was 990 lbs., or 1.8 lbs. per rated h.p.

Fig. 257. Longitudinal Section of King Airplane Engine.

The King engine was constructed mainly from aluminum, the form of construction differing from the Liberty engine which it was planned to replace. The crankcase was carried up to the top of the wet steel cylinder liners, and one aluminum head casting formed the combustion chambers for six cylinders.

There were three valves per cylinder; one inlet valve with a clear diameter of 3 in. and a lift of .5625 in., and two exhaust valves each with a clear diameter of 2.0625 in. and a lift of .4375 in. The inlet valve seat was cut at an angle of 10 degrees and the exhaust valve seat at 45 degrees. The

Fig. 258. Transverse Section and End View of King Engine.

valve seats were of steel, and were pressed into place. The camshaft was situated overhead between the slightly inclined inlet and exhaust valves, and was enclosed by an oil-tight cover which could be removed for making adjustments.

The crankshaft was a six-throw seven-bearing type supported in individual aluminum bearing caps. The propeller shaft was mounted in two annular ball bearings that were arranged so as to carry both radial and thrust loads. The connecting rods were of the articulated type and had "H" sections. Slipper type pistons, made from aluminum, were fitted with five rings above the wrist pin; the two upper ring grooves each contained two rings, and the single ring in the lower groove acted as an oil scraper.

An oil pressure of 45 lbs. was to be provided by a gear pump. Two carburetors, of special King design, were located at the rear of the engine, and each fed into a manifold cast in the cylinder head through a long water-jacketed pipe. Dual ignition was furnished by two Dixie magnetos.

KIRKHAM

The Kirkham engines were designed and built by Chas. B. Kirkham at Savona, N. Y., during 1910 and 1912. Mr. Kirkham, who is one of the earliest American airplane engine

builders, at one time was chief engineer of the Aeromarine Plane and Motor Company; and, while chief motor engineer of the Curtiss Airplane and Motor Corporation, developed the V2, and later the K-12 and K-6 models.

The cylinders of all Kirkham engines were cast separately from grey iron with water jackets integral. The combustion chamber was spherical in form, except for the two pockets at the spark plug bosses. Concentric type valves were operated through rockers and tubular concentric push rods from a camshaft situated in the crankcase.

The pistons were made from the same kind of material as the cylinders, and were fitted with two top rings. The piston pin was locked in the upper end of the connecting rod. The connecting rods had "H" sections with webs drilled out for lightness. The crankshafts used in all Kirkham engines had a bearing on either side of a crank throw. These bearings were made from Parson's white brass, the lower half being fitted into a maganese bronze cap which was held in place by two studs.

B-4. The Kirkham Model B-4 engine was a four-cylinder vertical water-cooled type of 4.125 in. bore, 4.75 in. stroke,

Fig. 259. Exhaust Side of Kirkham B-4 Engine.

Fig. 260. Inlet Side of Kirkham B-6 Engine.

and 253.92 cu. in. total displacement. This engine was rated 35/40 h.p. at 1400 r.p.m. and said to actually develop 40.4 h.p. at this speed. The total weight was reported to be 180 lbs., or 4.4 lbs. per actual h.p. The exhaust valve diameter was 2.375 in., the inlet valve diameter 2 in., and the lift of both .3125 in. The gasoline consumption per hr. at 1400 r.p.m. was said to be 24.5 lbs., and the oil consumption at the same speed 2.5 lbs.

B-6. The Model B-6 engine employed the same cylinders as the B-4 type and therefore had a total displacement of 380.88 cu. in. This engine was rated at 50 h.p., but was said to actually develop 54.5 h.p. at 1300 r.p.m. The complete weight was reported to be 235 lbs., or 4.3 lbs. per actual h.p. The gasoline consumption per hr. at 1300 r.p.m. was said to be 31.5 lbs., and the oil consumption at the same speed 3.25 lbs.

B-G-6. The Kirkham B-G-6 type was a six-cylinder vertical water-cooled geared engine, which operated normally at 1680 r.p.m. with a corresponding propeller speed of 960 r.p.m. The engine was rated at 70 h.p. and said to actually develop 76.3 h.p. at its normal speed. The bore was 4.3125 in., the stroke 5.125 in., and the total displacement 449.16 cu. in.

A four-cylinder vertical engine of 4.3125 in. bore, 5.125 in. stroke, and 299.44 cu. in. total displacement, was rated 50 h.p.

Fig. 261. The Kirkham Model B-G-6 Engine.

at 1350 r.p.m. This engine was quite similar to the B-G-6 design. It was said to weigh 190 lbs., or 3.8 lbs. per rated h.p.

KISHI

The Kishi was an air-cooled eight-cylinder Vee type engine entered in a contest held by the Imperial Aviation Association of Japan on June 22, 1917. This engine was rated 70 h.p. at 1400 r.p.m., but during the trials, in which it ran one hour and nineteen minutes, at no time developed more than 45 h.p. The bore was 96 mm. (3.78 in.), the stroke 120 mm. (4.72 in.), and the total displacement 423.83 cu. in. The weight was reported to be 455 lbs.

KNOX

During 1916, the Knox Motors Company of Springfield, Mass., brought out a water-cooled twelve-cylinder 60 degree Vee type geared engine, rated 300 h.p. at 1600 r.p.m. The bore was 4.75 in., the stroke 7 in., and the total displacement 1488.53 cu. in. The complete weight, including all equipment, was said to be 1400 lbs.

The cylinders were cast in blocks of three from aluminum, and fitted with cast-iron liners of ⅛ in. thickness which were pressed into place from the bottom. The cylinder heads were cast from aluminum in blocks of six with cast-iron valve seats cast integrally into place. The head was held down by sixteen studs which passed entirely through it. The four slightly inclined valves in each cylinder were operated through rocker arms from a centrally located camshaft carried in eight bearings. The rocker arms were supported above, and the entire valve mechanism was completely enclosed by an oil-tight aluminum cover.

Fig. 262. The Knox Twelve-Cylinder Engine.

The crankshaft had three large plain bearings. In the center of the engine, just above the crankshaft and driven by the timing gears, was a horizontal driveshaft with two integral spiral gears driving two vertical shafts with integral gears, that passed up through tubes into the cylinder head. Each vertical shaft extended on through a hollow short shaft and finally terminated in a splined end which received a splined cap piece that was bolted to the short hollow shaft to fix the relative positions of the camshaft and vertical drive shaft for timing purposes. The oil drainage from the cylinder head passed through these tubes in returning to the crankcase.

Fig. 263. Transverse Section of Knox 300-h.p. Engine.

The aluminum pistons had three rings, and the piston pin which was clamped in the upper end of the connecting rod, worked directly in the piston pin bosses. The connecting rods had "H" sections and two-bolt caps, and were arranged side by side on each crankpin. The propeller shaft was supported in double-row ball bearings, and carried a double-ball thrust bearing to take load in either direction. The starting gear which was attached to the propeller shaft was connected to the starting motor through a train of gears and a special roller clutch.

KOERTING

One of the early German built Koerting engines was a water-cooled eight-cylinder 90 degree Vee type which developed 65 h.p. at 1250 r.p.m. and 72 h.p. at 1400 r.p.m. This en-

Fig. 264. Side View and Longitudinal Section of Koerting 65-h.p. Engine.

gine had a 116 mm. (4.57 in.) bore, 126 mm. (4.96 in.) stroke, and a total displacement of 650.88 cu. in. The total weight was reported to be 440 lbs., and the fuel and oil consumption .66 and .044 lbs. per h.p-hr., respectively.

The cylinders were of the "L" head type with the inlet valve located directly over the exhaust. The inlet valves were operated through push rods and rockers, and the exhaust valves directly by tappets from a central camshaft in the Vee. The four - throw crankshaft was supported in five plain bearings, and the connecting rods were of the forked type with tubular sections. Ignition was supplied by magnetos.

Fig. 265. End View and Transverse Section of Koerting 65-h.p. Engine.

An eight-cylinder Vee type water-cooled engine of 110 mm. (4.33 in.) bore, 140 mm. (5.51 in.) stroke, and 649.12 cu. in. total displacement, was rated 185 h.p. at 2150 r.p.m. Plain spur reduction gears with .5 ratio were employed. The compression ratio was 4.91. The fuel consumption was said to be .547 lbs. per h.p-hr., and the total weight 556 lbs., or 3 lbs. per rated h.p. There were four valves per cylinder operated from overhead camshafts.

Fig. 266. The Koerting Twelve-Cylinder Engine.

The twelve-cylinder Vee type engine had a bore of 120 mm. (4.72 in.), a stroke of 140 mm. (5.51 in.), and a total displacement of 1156.92 cu. in. This engine was rated 250 h.p. at 1350 r.p.m. During tests the output was 252.5 h.p. at 1360 r.p.m. and the maximum 262 h.p. at 1750 r.p.m. The compression ratio was 4.52, and the total weight 992 lbs., or 3.97 lbs. per rated h.p.

The cylinders were constructed individually from steel with welded on sheet-metal water jackets. The inlet and exhaust valves stood vertically in the head along the longitudinal axis of the cylinders, and were operated through push rods from a camshaft that was mounted in a separate housing in the Vee.

The crankshaft had four bearings, and the connecting rods were forked. Herringbone reduction gears were employed, and the propeller shaft was mounted on ball bearings in a gear housing split along the horizontal. Two carburetors, mounted on each side of the engine, fed three cylinders each.

KRUK

The Kruk Engine Company of Germany built an air-cooled rotary engine of 130 mm. (5.12 in.) bore and stroke. A single valve operating in conjunction with a distributor was used for both inlet and exhaust. These functions were mechanically controlled.

LAMPLOUGH

The Lamplough six-cylinder two-cycle air-cooled rotary engine was exhibited at the Olympia show of 1911. A specially designed blower, incorporated within the crankcase,

Fig. 267. The Lamplough Two-Cycle Rotary Engine.

forced the gas mixture into the cylinder under slight pressure through ports that were overrun by the pistons near the end of their stroke. The exhaust gases simultaneously discharged into the open through the exhaust valves which were located in the cylinder head and operated by means of push rods and rockers. This system was claimed to have improved the scavenging of the burnt gases. The ignition was supplied by a magneto.

Lamplough is also reported to have built an air-cooled barrel type rotary engine.

LANCIA

The Lancia was an experimental engine designed and built in Italy during the war. There were twelve water-cooled cylinders arranged in 50 degree Vee form. The bore was 120 mm. (4.72 in.), the stroke 180 mm. (7.09 in.), and the total displacement 1488.72 cu. in. This engine was rated 320 h.p. at 1400 r.p.m., but under test developed 275 h.p. at 1250 r.p.m. and 305 h.p. at 1400 r.p.m.

Fig. 268. Propeller End of Lancia Twelve-Cylinder Engine.

Fig. 269. Timing End View of Lancia Twelve-Cylinder Engine.

The mixture was supplied by four Claudel carburetors. The lubricating system was of the dry sump type, an oil pressure of approximately 19 lbs. being maintained at the bearings. The oil supply was carried in a sheet-steel sump that was riveted to the lower-half crankcase.

The steel cylinder barrel was permanently screwed into a cast-iron head and a pressed-steel water jacket was welded to both. The lower flange was also welded in place, and lugs were provided on top for bolting two adjacent cylinders together for the sake of rigidity. The valves were placed horizontally in respect to the cylinder axis and were operated through long rocker arms in a manner quite similar to the Duesenberg engines. A camshaft located in the Vee was driven by a train of spur gears.

The crankshaft was a six-throw three-bearing type. The connecting rods had "H" sections and were placed side by side upon the crankpins. The aluminum pistons employed three top rings, and dual ignition was supplied by two twelve-cylinder Dixie magnetos. The dry weight was reported to be 740 lbs., or 2.69 lbs. per rated h.p.

LAVIATOR

The French Laviator Company exhibited two six-cylinder two-cycle engines at the Paris Aero Show in 1913. A bore of 100 mm. (3.94 in.), a stroke of 130 mm. (5.12 in.), and a total displacement of 374.52 cu. in. was common to both engines. One of these engines was air-cooled, and at 1200 r.p.m. it was rated 65 h.p. when used as a radial and 50 h.p. as a rotary. The weight was said to be 198 lbs., or 3.05 lbs. per h.p. as a radial and 3.96 lbs. per h.p. as a rotary. The water-cooled model operated at a higher speed and was rated 80 h.p. at 1300 r.p.m. The weight was said to be 242 lbs., or 3.02 lbs. per rated h.p.

The cylinders had two diameters, that part farthest from center having the smallest diameter and constituted the working cylinder. The inner cylinder, of the larger diameter, operated as a pumping cylinder, and was connected by external piping to the working cylinder 120 degrees in advance of it in the direction of rotation, and by other pipes to the crank chamber. Ports were so formed that openings in the surface of the hollow crankshaft, which was in communication with the carburetor, registered successively with the conduits leading to the pumping cylinders. In this manner the charge was first drawn into the pumping cylinder and then forced into the cylinder 120 degrees in advance. The fresh charge scavenged the burnt gases of the previous stroke from the exhaust ports that were formed in the base of the working cylinder.

In the water-cooled model, the cooling water entered the jacket at the head of the left-hand lower cylinder, passing out near the base of that jacket to the inner end of the jacket of the next cylinder, and so on around until it is finally discharged from the head of the lower-most right-hand cylinder.

The jackets were held in position by shrinking steel rings over the inner ends.

There have also been built four-stroke water-cooled Laviator engines in vertical and Vee arrangement. A four-cylinder vertical type of 145 mm. (5.71 in.) bore, 175 mm. (6.89 in.) stroke, and 705.72 cu. in. total displacement, was rated 120 h.p. at 1200 r.p.m. The propeller was mounted on the camshaft and therefore ran at one-half engine speed. The weight was reported to be 484 lbs., or 4.03 lbs. per rated h.p.

Fig. 270. The Laviator Two-Cycle Engine.

A six-cylinder vertical model, rated 110 h.p at 1100 r.p.m., had a 130 mm. (5.12 in.) bore, 160 mm. (6.3 in.) stroke, and a total displacement of 777.66 cu. in. The propeller was also mounted on the camshaft, and the valves were of the concentric type. The weight was reported to be 616 lbs., or 5.6 lbs. per rated h.p.

The larger six-cylinder vertical water-cooled type, rated 250 h.p. at 1050 r.p.m., had a 180 mm. (7.09 in.) bore, 200 mm. (7.87 in.) stroke, and a total displacement of 1864.26 cu. in. Concentric valves in the cylinder head were operated through push rods and rockers. The weight was said to be 1210 lbs., or 4.84 lbs. per rated h.p.

The propeller was driven from the camshaft on all of the eight-cylinder models, and the valves were of the concentric

type. The cylinders were made separately from steel with cast inlet and exhaust ports that were bolted to the head and not water-cooled. A single Zenith or Claudel carburetor was fitted to supply each group of four cylinders separately. Ignition was by one magneto.

The smaller of the eight-cylinder 90 degree Vee type engines was rated 80 h.p. at 1200 r.p.m. The bore was 100 mm. (3.94 in.), the stroke 130 mm. (5.12 in.), and the total displacement 499.36 cu. in. The weight was reported to be 275 lbs., or 3.44 lbs. per rated h.p.

The eight-cylinder model, rated 120 h.p. at 1200 r.p.m., had a 114 mm. (4.48 in.) bore, 160 mm. (6.3 in.) stroke, and a total displacement of 794.48 cu. in. The weight was stated to be 418 lbs., or 3.48 lbs. per rated h.p.

The larger eight-cylinder model, had 145 mm. (5.71 in.) bore, 175 mm. (6.89 in.) stroke, and a total displacement of 1411.44 cu. in. This engine was rated 200 h.p. at 1100 r.p.m. and reported to weigh 715 lbs., or 3.58 lbs. per rated h.p.

LAWRANCE

The Model A Lawrance-Moulton airplane engine was built in France and exhibited at the Fifth International Exposition held in Paris during 1913. The Model B, built in the United States in the years 1916 and 1917, was an eight-cylinder 90 degree Vee type engine rated 200 h.p. at 1800 r.p.m. The bore was 4.75 in., the stroke 6.5 in., and the total displacement 921.52 cu. in. The weight including exhaust manifolds was reported to be 916 lbs., and without 876 lbs.

The propeller drive was by reduction gears having any desired ratio from .33 to .66, the standard equipment being .5. A duplex Zenith carburetor was situated in the Vee, and dual ignition was by two eight-cylinder Dixie magnetos with battery ignition for starting purposes. The cooling water was circulated by a centrifugal pump with one impeller, and an outlet to each row of cylinders. A gear pump was mounted under the sump and delivered oil to the bearings under high pressure through external pipes.

The connecting rods were of the forked type. An inlet valve of 2.4375 in. clear diameter and an exhaust valve of 1.75 in. clear diameter both lifted .625 in. There was also an

Fig. 271. Propeller End of Lawrance-Moulton Engine.

auxiliary exhaust consisting of a rotary valve running at quarter engine speed that was open at the bottom of the stroke. The valve timing was as follows: the inlet opened 15.5 degrees late and closed 59.5 degrees late; the exhaust opened 32 degrees early and closed 12 degrees late, the auxiliary exhaust opening and closing at 50 degrees each side of bottom center piston position.

Fig. 272. Lawrance-Moulton 200-h.p. Engine.

Model A-3. The Lawrance Model A-3 engine, designed during 1916, was an air-cooled two-cylinder horizontally opposed type which developed 28 h.p. at 1400 r.p.m. These engines were used in "Penguin" training machines for instructing the pilot in the use of his controls while still running on the ground.

Fig. 273. The Lawrance Model A-3 Engine.

Model N-2. The Type N-2 Lawrance two-cylinder horizontally opposed air-cooled engines were built experimentally for the U. S. Navy. The bore and stroke were 4.25 in., and the total displacement 120.58 cu. in. These engines were rated 40 h.p. at 1900 r.p.m., and weighed 79 lbs., or 1.97 lbs. per rated h.p. This type was later abandoned in favor of the Model L.

The mixture was furnished by two Zenith horizontal type carburetors, and dual ignition by a Philbrin battery system. The crankshaft had a single throw, and the propeller speed was reduced through gearing. The valves were interchangeable, their timing being as follows: the inlet opened 5 degrees early and closed 50 degrees late; the exhaust opened 45 degrees early and closed 15 degrees late.

Fig. 274. The Lawrance Model N-2 Engine.

Model B. The Lawrance Model B engine was originally built in 1916, and the experiments made with it contributed to a large degree in the successful development of the L types.

Fig. 275. The Lawrance Model B Engine.

Model B was an air-cooled three-cylinder radial engine, in which the output was increased during tests from 35 to 60 h.p.

Model L-2. The Model L-2 engine is now marketed by the Lawrance Aero Engine Corporation of 644 W. 44th Street, New York City. This is an air-cooled three-cylinder radial engine which develops 56.5 h.p. at a normal speed of 1600 r.

Fig. 276. Propeller End of Lawrance Model L-2 Engine.

p.m. and 65 h.p. at 2000 r.p.m. The bore is 4.25 in., the stroke 5.25 in., and the total displacement 223.44 cu. in. The compression ratio is 5.14, and the maximum brake mean effective pressure is 125 lbs. per sq. in. at 1600 r.p.m.

An M-4 Stromberg carburetor, of 1.312 in. choke and No. 30 jet, furnishes the mixture. An oil pressure of 11 lbs. is maintained by a gear pump running at ½ engine speed. The oil supply is carried in a sump in the lower part of the crank-case. The consumption of fuel is .512 lbs. per h.p-hr., and the consumption of oil .04 lbs. per h.p-hr.

Fig. 277. Timing End of Lawrance Model L-2 Engine.

The cylinders and cooling fins are cast from aluminum and fitted with steel liners pressed into place. The inlet and exhaust valves have 30 degree seats, are 2 in. in diameter, and have a lift of .47 in. The cold valve timing is as follows: the

inlet opens 42 degrees early and closes 90 degrees late; the exhaust opens 92 degrees early and closes 46 degrees late.

The single-throw crankshaft is made solid with the counterweights bolted on, and the connecting rods are of the slipper type with tubular sections. The aluminum pistons are fitted with five rings, the lower ring being used as an oil scraper. Battery type of ignition is employed, and the engine weighs 147.4 lbs., or 2.6 lbs. per rated h.p.

Fig. 278. The Lawrance Model L-3 Engine.

Model L-3. The Lawrance Model L-3 is an improved L-2 design, the oil tank now being made separate from the engine and helical valve springs replacing the volute ribbon type.

Model L-5. The latest three - cylinder air - cooled radial design produced by Lawrance varies from the L-3 Model principally in the substitution of Dixie magnetos for the battery type ignition.

Nine-Cylinder. Nine of the L-2 type cylinders were employed in a 140-h.p. radial engine produced experimentally for the Engineering Division of the Air-Service. A similar engine with nine cylinders of .25 in. larger bore and rated at 200 h.p. is now being built for the Navy Department.

Fig. 279. The Lawrance Model L-5 Engine.

LE GAUCEAR

The LeGaucear was a ten-cylinder air-cooled Monosoupape rotary engine of 150 h.p. that was built in America during 1915. The cylinders were of steel construction, and the valves were operated individually through push rods from ten individual cams in the nose piece. The springs were located on the cam follower instead of at the valve according to the usual practice. The valve seated on a cage which was held in the cylinder head by a castellated ring. The two-throw crankshaft and the master connecting rods of the articulated system were mounted on ball bearings. A magneto furnished the ignition.

Fig. 280. The LeGaucear Monosoupape Rotary Engine.

LE MAITRE AND GERARD

An experimental eight-cylinder 90 degree Vee type water-cooled engine has been built in France by LeMaitre and Gerard. The bore is 180 mm. (7.09 in.), the stroke 210 mm. (8.27 in.), and the total displacement 2612 cu. in. The engine is arranged for direct driven propeller, and is rated 700 h.p. at 1600 r.p.m. The weight is reported to be 1260 lbs.

The cylinders are cast in blocks of four from aluminum, and encase steel liners whose outer surfaces are exposed to the cooling water. There are four valves of 2 in. diameter in each cylinder. The special means provided for cooling the exhaust valves is of interest. A blower running at three and one-third times engine speed is mounted in the Vee and driven by a vertical shaft which also drives the water pump. Air is drawn through ducts in the overhead camshaft cover, thence into the valves and down the stems, discharging through a series of holes placed around the cone portion of the valve.

LE RHONE

Le Rhone air-cooled rotary engines are built by the Société des Moteurs Gnôme et Rhône, 41 Rue La Boétie, Paris, France, and by The Gnome and Le Rhone Engine Co., 47 Victoria Street, Westminster, London, S. W. England. The Type C 80-h.p. engine was also produced in America during the war by the Union Switch and Signal Company of Swissvale, Pennsylvania.

Le Rhone engine cylinders are machined with integral cooling flanges from steel forgings and the working barrels fitted with cast-iron liners. The lower ends of the cylinders screw into the steel crankcase and are secured by lock rings. Single inlet and exhaust valves seat in each cylinder head and are operated by a single push rod and oscillating rocker arm that is supported on ball bearings. The valve springs only hold the valves closed while starting, the centrifugal force being depended upon during running. With the exception of some of the later models, Le Rhone pistons are generally made from cast-iron and fitted with special tungsten steel rings.

The valve mechanism consists of two cams operating a cam rocker connected to each push rod. The cam rocker receives an oscillating motion through the contact of the inlet and exhaust cam rollers on their respective cams. The cam profile is repeated half the number of cylinders plus one, and moves in proper relation to the cylinders by internally meshed gears mounted eccentrically. Centrifugal force tends to hold the inlet cam roller hard on its cam. The two cams are

bolted to a cam boss which is freely mounted on ball bearings.

The propeller hub is integral with the front cover of the steel crankcase. The fixed crankshaft is of built-up construction and supports the crankcase and connecting rod assemblies on ball bearings; a double-row ball thrust bearing is located near the rear of the engine. The connecting rods are of the slipper type and have "H" sections. The gas mixture enters

Fig. 281. Transverse Section of 80-h.p. Le Rhone Engine.

the crank compartment through the hollow fixed crankshaft from a carburetor at the rear, and is then led to the cylinders through copper inlet pipes by centrifugal force.

Several of the Rhone engines were built with a 105 mm. (4.13 in.) bore and 140 mm. (5.51 in.) stroke. The smaller, a seven-cylinder model with a total displacement of 516.67 cu.

in., was rated 50 h.p. at 1200 r.p.m. The weight was said to be 183 lbs., or 3.67 lbs. per rated h.p.

The Model C, a nine-cylinder engine rated 80 h.p. at 1200 r.p.m., was used more extensively than any other of this series. The total displacement was 664.29 cu. in., and the compression ratio 4.8 to 1. The fuel consumption was reported to be .57 lbs. per h.p-hr., and the oil consumption .094 lbs. per h.p-hr. The total weight was said to be 253 lbs., or 3.16 lbs. per rated h.p.

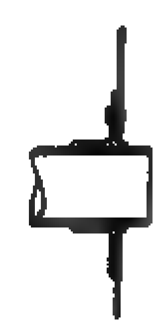


Fig. 282. Longitudinal Section of 80-h.p. Le Rhone Engine.

The valves were of 1.8 in. diameter and had 36.5 degree seats. The valve timing was as follows: the inlet opened 18 degrees late and closed 34 degrees late; the exhaust opened 38 degrees early and closed 6 degrees late.

An eleven-cylinder engine of this series, with a total displacement of 811.91 cu. in., was rated 100 h.p. at 1200 r.p.m.

and said to weigh 297 lbs.

The fourteen-cylinder model, rated 120 h.p. at 1200 r.p.m., was in reality a double form of the smaller engine. The total displacement was 1033.34 cu. in., and the weight was said to be 375 lbs., or 3.12 lbs. per rated h.p.

A double form of the Model C was rated 160 h.p. at 1200 r.p.m. The eighteen cylinders had a total displacement of 1328.58 cu. in., and the weight was said to be 464 lbs., or 2.9 lbs. per rated h.p.

Model J. The Model J engine is more frequently referred to as the 110-h.p. Le Rhone. It is a nine-cylinder rotary of 112 mm. (4.41 in.) bore, 170 mm. (6.69 in.) stroke, and a total displacement of 919.71 cu. in. The torque reaction at 1200 r.p.m. amounts to 127 h.p., the useful horsepower developed being 112. The compression ratio is 5 to 1, and the complete weight of the engine is said to be 323 lbs., or 2.93 lbs. per rated h.p. The consumption of fuel at normal output is .69 lbs. per h.p-hr., and that of oil .1 lbs. per h.p-hr.

The cam mechanism is at the rear of the engine instead of at the propeller end as per usual practice. The inlet and exhaust valve each have a clear diameter of 45 mm. (1.77 in.) and lift 10.5 mm. (.413 in.). The timing of the valves is as follows: the inlet opens and closes 30 degrees late; the exhaust opens from 40 to 45 degrees early and closes 16 degrees late.

Model R. Le Rhone Model R, developed during the war, is a nine-cylinder rotary engine of 115 mm. (4.53 in.) bore, 170 mm. (6.69 in.) stroke, and 970.38 cu. in. total displacement. At 1360 r.p.m. the normal output is 170 h.p. and the maximum 180 h.p. The compression ratio is 5.65 to 1. The complete weight is said to be 392 lbs., or 2.3 lbs. per normal rated h.p.

The inlet valve diameter is 52 mm. (2.047 in.), and the exhaust valve diameter is 50 mm. (1.97 in.). The lift of both valves is 11 mm. (.433 in.). The inlet valve opens 20 degrees late and closes 40 degrees late; the exhaust valve opens 60 degrees early and closes 15 degrees late.

The new features introduced in the Model R engine are: high compression, aluminum pistons, new type of induction system, and a cooling device for the interior in the form of

nine air intakes projecting from the front of the crankcase. Dual ignition is provided. The fuel consumption is reported to be .65 lbs. per h.p-hr., and the oil consumption .093 lbs. per h.p-hr. The overall dimensions are: length 39.56 in., and outside diameter 39.64 in.

Fig. 283. The Model J. 110-h.p. Le Rhone Rotary Engine.

Model Z. One of the late Le Rhone developments is the Model Z, a seven-cylinder air-cooled rotary engine said to develop 40 h.p. at 1300 r.p.m. and 63 h.p. at 1450 r.p.m. The bore is 85 mm. (3.35 in.), the stroke 105 mm. (4.13 in.), and the total displacement 254.8 cu. in. This engine is equipped with dual ignition. The consumption of fuel is said to be .518 lbs. per h.p-hr., and the consumption of oil .11 lbs. per h.p-hr. The weight is reported as 144 lbs., or 3.6 lbs. per h.p. developed at 1300 r.p.m.

Model Z-60. A nine-cylinder Le Rhone, known as Model Z-60, is a compact design recently developed for civil aviation

The bore is 84 mm. (3.31 in.), the stroke 100 mm. (3.94 in.), and the total displacement 305.1 cu. in. This engine is rated 60 h.p. at 1400 r.p.m. and said to weigh 150 lbs., or 2.5 lbs. per rated h.p.

LEVI

The Levi was a French built experimental barrel type engine of seven valveless cylinders.

LIBERTY

The purpose of developing the Liberty engines was to provide standard units that could be produced in large quantities by American manufacturers, and moreover meet the requirements of airplane engines at the time the United States entered the war. No American design had been sufficiently developed to adopt as a standard, nor was it believed that any of the European designs, many of which were rapidly becoming obsolete, could be readily produced by American manufacturing methods.

The idea of developing standard engine types was first thought of about May 25, 1917, and was further developed in a conference with representatives of the British and French Missions held from May 28 to June 1. The proposal was submitted in the form of sketches to a joint Army and Navy Technical Board on June 4, and the first eight-cylinder model was delivered to the Bureau of Standards on July 3, 1917. The eight-cylinder model, however, was never produced in large quantities, one of the reasons being that reports from France indicated power requirements would make this type obsolete before it could be put into service. The twelve-cylinder Liberty was then built and this engine was said to have passed a fifty-hour test on August 25, 1917.

Contrary to many rumors circulated at the time, the Liberty engine was not an invention. The design was based on the practice of several well-known American and European manufacturers that had been proven in service. The success of the Liberty engine was due entirely to the fact that some of the best engineers, production experts, and facilities for manufacturing were at the Government's disposal. Due to

Fig. 284. Transverse Section of Liberty Engine.

this pooling of interests and consulations held with various experts, individual credit for design cannot justly be accorded.

Liberty 12-A. The Liberty 12-A engine, the only one of the series to be produced in large quantities, has two rows of six cylinders with an included angle of 45 degrees. The bore is 5 in., the stroke 7 in., and the total displacement 1648.92 cu. in. The Navy type engines employ a compression ratio of 5

Fig. 285. Transverse Section through Camshaft Drive of Liberty Engine.

and the Army type 5.42, the difference being due to the altitudes at which the engines are generally used.

The higher compression engine develops 421 h.p. at the maximum normal speed of 1700 r.p.m.; the maximum horsepower, which is developed at 1940 r.p.m., is 449. At 1540 r.p.

Fig. 286. Longitudinal Section of Liberty 12-A.

Fig. 287. End View of Liberty 12-A.

m., 119.5 lbs. per sq. in. b.m.e.p. is the maximum developed. At normal outputs the fuel consumption is .496 lbs. per h.p-hr., and the oil consumption is .032 lbs. per h.p-hr. The dry weight of the Liberty 12-A engine is 844 lbs., or 2 lbs. per actual h.p. The battery, switch, and voltage regulator weigh 13 lbs., and the water content of the engine is 45 lbs.

The cylinders are made separately from steel forgings and have pressed-steel water jackets welded in place. The cylinder barrel and combustion chamber are forged integral; the swaging process developed by the Ford Motor Company being virtually the closing of the end of a tube. The valve ports are made from steel forgings and welded to the cylinder head. The inlet water enters the cylinder on a tangent and leaves by a pipe that extends in toward the exhaust port to

Fig. 288. Side View of Liberty 12-A.

receive the water at the hottest part of cylinder and is perforated for relieving steam pockets.

An inlet and exhaust valve, each with 2.5 in. clear diameter and 30 degree seats, are inclined to the vertical axis of the cylinder. The inlet valve lift is .4375 in. and the exhaust valve lift is .375 in. The valve timing is as follows: the inlet opens 10 degrees late and closes 45 degrees late; the exhaust opens 48 degrees early and closes 8 degrees late. The valves are operated by rockers from an overhead camshaft

supported in seven split aluminum bearings. These bearings are stepped in outside diameter to permit sliding the assembly into an aluminum housing super-imposed upon six cylinders and held down by two studs to each one. The valve rockers are of an improved Mercedes type designed by Mr. Allen Loomis at the Packard Motor Car Co. Each camshaft is driven by a vertical shaft and bevel gears.

Fig. 289. Propeller End of Liberty 12-A.

The crankshaft is a conventional six-throw type supported in seven plain bearings. The connecting rods are of the forked type with "H" sections, and the aluminum ("Lynite") pistons are fitted with three top rings. The lubricating system is of the dry-sump pressure-feed type, the oil being delivered to the bearings by a gear pump attached to the lower-half crankcase. The cooling water is circulated by a centrifugal

pump with two outlets. Two Zenith duplex (U. S. No. 52) carburetors are located in the Vee. Ignition of the Delco Battery type consists of a low voltage generator, an eight-volt storage battery, and a double distributor system. The distributors are located at the driving ends of the camshaft housing, and the two spark plugs are situated almost vertically in each cylinder head directly underneath the camshaft housing. The approximate overall dimensions of the Liberty 12-A engine are as follows: length over propeller hub 67.375 in., width 27 in., and height 41.5 in.

Fig. 290. The Liberty Eight-Cylinder Engine.

Liberty-Eight. The eight-cylinder Liberty is a 45 degree Vee type almost identical in design to the 12-A model. The total displacement is 1099.28 cu. in. This engine develops normally 290 h.p. at 1700 r.p.m. and 317 h.p. at a maximum speed of 2000 r.p.m. The maximum brake mean effective pressure is 127 lbs. per sq. in. and occurs at 1200 r.p.m. The fuel consumption at normal output is .49 lbs. per h.p-hr., and the oil consumption .021 lbs. per h.p-hr. The total dry weight is 638 lbs., or 2.2 lbs. per normal h.p.; and the water content of the engine is 28 lbs. The extreme overall length is approximately 57 in.

Liberty-Six. The six-cylinder vertical engine shows the best performance of any of the Liberty series. At 1700 r.p.m an output of 231 h.p. has been obtained, and the maximum developed at 1850 r.p.m. was 240 h.p. The total displacement is 824.46 cu. in. The brake mean effective pressure is 130.5 lbs. per sq. in. at the normal speed, and the maximum is 132 lbs. per sq. in. at 1500 r.p.m. At normal output the fuel consumption is .526 lbs. per h.p-hr., and the oil consumption .026 lbs. per h.p-hr. The total dry weight is 567.5 lbs., or 2.45 lbs. per normal h.p. The overall dimensions are as follows: length 68 in., width 19.5 in., and height 43 in.

The only six Liberty-Six engines built during the war were manufactured by the Thomas-Morse Aircraft Corporation of Ithaca, N. Y. During 1920, the Liberty-Six was redesigned at McCook Field and ten engines ordered under contract; the new designs were provided with magneto ignition.

Fig. 291. End View of Liberty-Six.

Fig. 292. Side View of Liberty-Six.

more compact intake manifolds, and gun synchronizer drive.

Liberty-Four. The four-cylinder Liberty engines were rated at 100 h.p. A very limited number of these engines were built by the Hudson Motor Car Company at Detroit, Michigan, and none are known to have been used in actual flight.

Liberty Double-Crankshaft. An experimental engine built by the Packard Motor Car Company at Detroit, Michigan, was arranged similar to the sixteen-cylinder Bugatti design, except that each row of six cylinders was inclined at the same angle to the vertical plane as in the standard Liberty 12-A. The two crankshafts were geared to a common propeller shaft, that was made hollow to permit the firing of a cannon properly mounted upon the crankcase between each row of cylinders. This engine was never developed.

Fig. 293. The Liberty Double-Crankshaft Type.

Liberty 12-C. Among some of the attempts to produce a twelve-cylinder Liberty with geared propeller drive, was the 12-C Model with plain spur reduction gears having a ratio of .666. After being tested and flown in an experimental airplane the design was abandoned.

Liberty Epicyclics. The well-known epicyclic gear reduction, that has been so consistently used in the Rolls-Royce engines, was also tried. The Rolls-Royce design, however, was slightly modified in its new application. After several months of experimenting, the Army finally turned the design over to the Navy Department. The Allison Engineering Company of Indianapolis, Indiana, further developed the design for the Navy, and the re-modeled engines which they now build are capable of passing successful tests when not run over 1700 r.p.m., the safe normal speed of the engine.

LORRAINE-DIETRICH

The serious shortage of reliable airplane engines in France at the outbreak of the war was keenly felt. Among the number of firms then to undertake airplane engine design and development was Lorraine-Dietrich, who, under the direction of Engineer Barbarou, first brought out a six-cylinder vertical 150-h.p. engine similar to the Mercedes design, which was installed in service planes during 1915.

This engine was shortly followed by an eight-cylinder water-cooled Vee type of 120 mm. (4.72 in.) bore, 140 mm. (5.51 in.) stroke, and 771.28 cu. in. total displacement, which was rated at 160 h.p.

The demand for higher power led to increasing the length of the stroke, the next Lorraine-Dietrich design being an eight-cylinder Vee type of 120 mm. (4.72 in.) bore, 170 mm. (6.69 in.) stroke, and 936.48 cu. in. total displacement. This engine was rated 220 h.p. at 1350 r.p.m., and said to develop 245 h.p. at 1500 r.p.m. and 275 h.p. at 1750 r.p.m.

Type 12-E. A twelve-cylinder 60 degree Vee engine, known as Type 12-E, having the same (120 mm. x 170 mm.) bore and stroke, and a total displacement of 1404.72 cu. in., was said to develop normally 342 h.p. at 1500 r.p.m. and 400 h.p. at 1800 r.p.m. The weight was reported to be 770 lbs., or 2.25 lbs. per normal h.p. The compression ratio was 5.25 to 1.

The fuel consumption was said to be .55 lbs. per h.p-hr., and the oil consumption .035 lbs. per h.p-hr. Oil was delivered to the bearings under pressure by a duplex valveless oscillating piston pump. The cooling water was circulated by a

Fig. 294. The Lorraine-Dietrich 220-h.p. Engine.

centrifugal pump with two outlets. Dual ignition was furnished by two six-cylinder Gibaud magnetos, the distributors being mounted on the end of the camshaft housing.

Fig. 295. The Lorraine-Dietrich Type 12E.

The cylinders were machined from steel forgings and welded together in pairs, a common sheet-metal water jacket encasing each pair of cylinders. The inlet and exhaust valves were inclined in the cylinder head and operated by an overhead camshaft through rocker arms. The six-throw camshaft was supported in four plain bearings, and the forked type connecting rods had tubular sections. The thrust side of the aluminum piston was supplied with oil under pressure by a lead through the rod and around the wrist pin which was locked in place.

Type 14. The twelve-cylinder Lorraine-Dietrich engine, known as Type 14, was arranged in three rows of four cylinders each, with the two outer sets at 60 degrees to the vertical. The design was similar and the cylinder dimensions identical to the 12-E type. The output was said to be 358 h.p. at 1500 r.p.m. and 422 h.p. at 1800 r.p.m.

Type 8Bd. A Lorraine-Dietrich series having a 120 mm. (4.72 in.) bore and 175 mm. (6.89 in.) stroke, began with Type 8 Bd., an eight-cylinder Vee engine of 964.48 cu. in. total displacement. Normally rated at 250 h.p., the 8 Bd type was said to develop 275 h.p. at 1650 r.p.m. and 305 h.p. at 1900 r.p.m. The compression ratio was 4.7 to 1, and the total dry weight was reported to be 547 lbs., or 2.19 lbs. per rated h.p.

Type 13. A twelve-cylinder 60 degree Vee type engine of this series, which had a total displacement of 1446.72 cu. in., was said to develop normally 354 h.p. at 1500 r.p.m. and 415 h.p. at 1800 r.p.m. Type 13 closely resembled the 12E model.

Type 17. The Lorraine-Dietrich Type 17 was an improved Type 13 engine, rated at 400 h.p. The output was reported to be 407 h.p. at 1600 r.p.m. and 438 h.p. at 1700 r.p.m. The compression ratio was 5 to 1. The total weight was said to be 823 lbs., or 2.05 lbs. per rated h.p.

Type 15. The twelve-cylinder W type, of 120 mm. bore and 175 mm. stroke, was said to develop normally 370 h.p. at 1500 r.p.m. and 435 h.p. at 1800 r.p.m. The weight was approximately 720 lbs., or 1.94 lbs. per normal h.p.

The four-throw crankshaft was supported in three plain bearings, and the connecting rods were all made with tubular sections. The two outer rods had their bearing on the outside

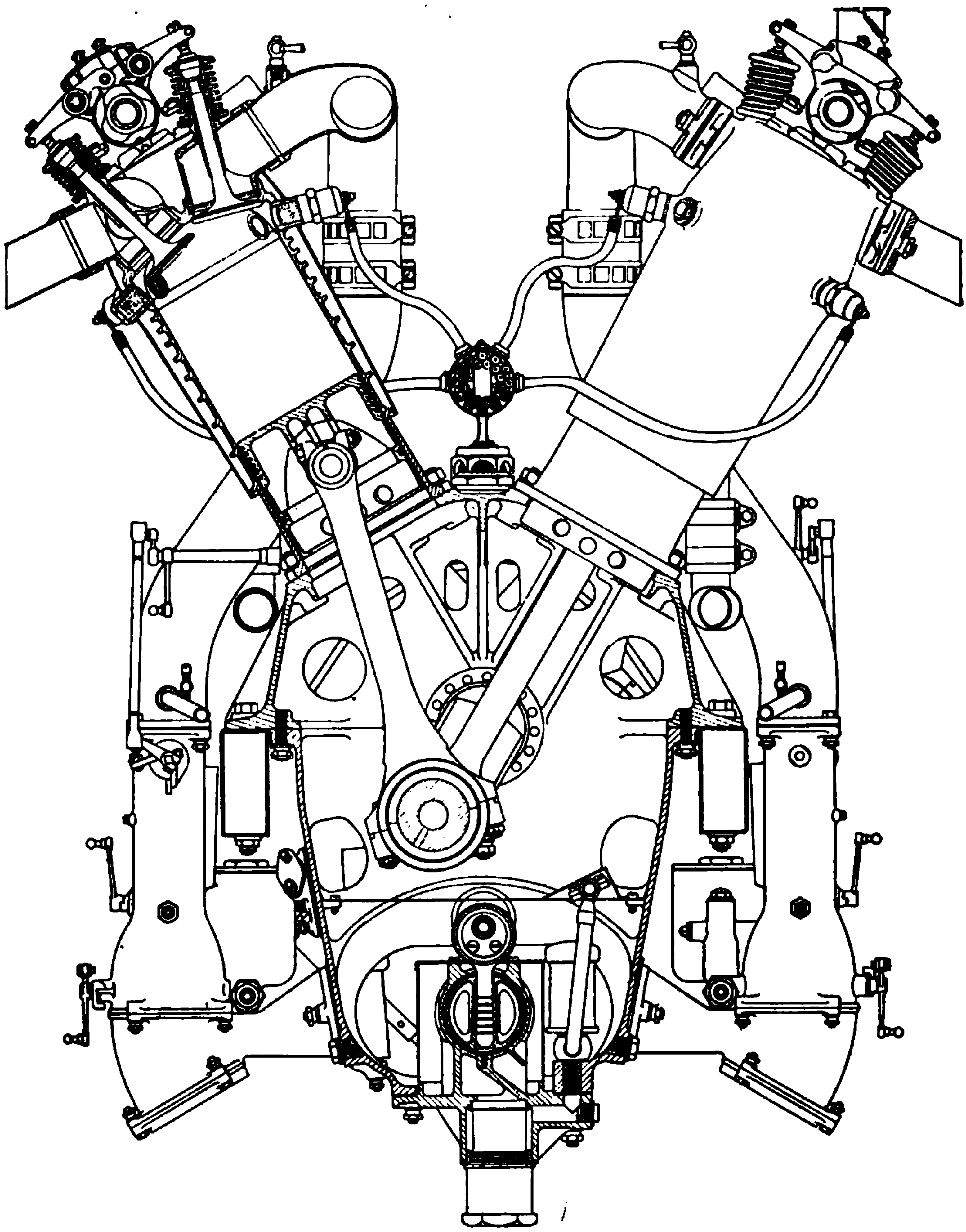


Fig. 296. Transverse Section of Lorraine-Dietrich Twelve-Cylinder Engine.

surface of the center or master connecting rod for a distance somewhat less than half the circumference, and were held to it by two circular rings bolted together longitudinally. The engine was equipped with three carburetors, one for each row of four cylinders.

Type 16. Another Lorraine-Dietrich series was built with a 120 mm. (4.72 in.) bore and 180 mm. (7.09 in.) stroke. Type 16, an eight-cylinder 90 degree Vee type of 992.48 cu. in.

total displacement, was rated at 300 h.p. The weight was said to be 587 lbs., or 1.96 lbs. per rated h.p.

Type 18. The twelve-cylinder 60 degree Vee type engine, of 1488.72 cu. in. total displacement, was rated at 450 h.p. The weight was said to be 846 lbs., or 1.88 lbs. per rated h.p.

Fig. 298. The Lorraine-Dietrich Type 13.

A twelve-cylinder 60 degree Vee type engine of 120 mm. (4.72 in.) bore, 200 mm. (7.87 in.) stroke, and 1652.4 cu. in. total displacement, was estimated to develop 600 h.p. The compression ratio was 5.2 to 1, and the weight was reported to be 940 lbs., or 1.57 lbs. per estimated h.p.

The latest Lorraine-Dietrich series have a 126 mm. (4.96 in.) bore and 200 mm. (7.87 in.) stroke. The twelve-cylinder 60 degree Vee type, of 1824.72 cu. in. total displacement, is rated at 500 h.p. This engine is said to develop 525 h.p. at 1600 r.p.m., and weigh 1014 lbs., or 2.03 lbs. per rated h.p.

The cylinders are constructed in pairs, steel cylinder barrels being welded into cast-iron heads. The inlet and two ex-

Fig. 299. The Lorraine-Dietrich W Type Engine.

haust valves in the cylinder head are operated from one camshaft in the Vee by push rods and rockers that are enclosed in a grease-tight housing. The camshaft has twelve exhaust and six inlet cams integrally attached.

The six-throw four-bearing crankshaft is supported in bearing caps, and the connecting rods are a special Lorraine

Fig. 300. The Lorraine-Dietrich 500-h.p. Engine.

patented design. The aluminum pistons are fitted with five top rings and one lower oil scraper ring.

The mixture is supplied by two duplex carburetors, and the pressure of the lubricating system is maintained by a valveless oscillating barrel type pump. The centrifugal water pump has a double outlet, and dual ignition is supplied by two m

Fig. 301. The Lorraine-Dietrich 500-h.p. W Type.

The twelve-cylinder W type engine, of 126 mm. bore and 200 mm. stroke, is similar in construction to the twelve-cylinder Vee type of the same displacement. This engine is also rated at 500 h.p. and said to develop 525 h.p. at 1600 r.p.m. The weight is reported as 960 lbs., or 1.92 lbs. per rated h.p.

The crankshaft has four throws and is supported in three plain bearings. The connecting rods are constructed practically the same as those employed on one of the earlier Lorraine-Dietrich W types. There are two camshafts situated in the Vee, one on either side of the vertical row of cylinders.

At the signing of the Armistice, Lorraine-Dietrich were engaged in designing a twenty four-cylinder unit. This engine

is composed of three rows of eight cylinders each, the two outer rows being set at 60 degrees to the vertical as in the case of the twelve-cylinder W types. In reality it might be said that the unit is formed of two 500-h.p. W type engines joined at ends.

Fig. 302. The Lorraine-Dietrich 1000-h.p. Engine.

The twenty-four cylinder engine has a total displacement of 3649.44 cu. in. and is rated 1000 h.p. at 1600 r.p.m. The weight is estimated at 1874 lbs., or 1.87 lbs. per rated h.p.

The cylinders and connecting rods are the same as those used in the 500-h.p. W type engine. The crankshaft has eight throws and five main bearings. The carburetors are located on the outside, and two oil pumps from the smaller 500-h.p. model are fitted. The space in the crankcase between the center and each outer row of cylinders is occupied by a camshaft. For ignition two Delco generators feed four distributors which have twelve contact plugs each. Starting is accomplished by compressed air with connections only in the six end cylinders.

M. A. B.

The M. A. B. engines were designed and constructed in Italy, each of the two types known to have been built had four cylinders. One was an air-cooled fan type having cylinders cast from iron with integral cooling fins, and the other was a vertical water-cooled engine in which the separately constructed cylinders had overhead valves operated by means of push rods. A centrifugal pump circulated the cooling water, and magnetos supplied the ignition.

Fig. 303. The M. A. B. Fan Type Engine.

MACOMBER

The Macomber was an American built air-cooled barrel rotary engine having seven cylinders with axes parallel to a central shaft. Ball and socket joints at each end of the con-

Fig. 304. The M. A. B. Four-Cylinder Vertical Engine.

necting rod joined the pistons and the wobble plate which revolved with the cylinders. Special means were provided for varying the angle of the wobble plate, thereby effecting a change in the length of stroke and the compression ratio. Ball bearings were used throughout. The valves were located in the cylinder head, the inlets nearest the center and the exhausts to the outside, and operated from a single rocker, pivoted between them, which had one end sliding in a central grooved cam.

Fig. 305. The Macomber Seven-Cylinder Rotary Engine.

M. A. N.

The German submarine Diesel engines were the best known of the M. A. N. products. The works were located at the two cities included in the name "Maschinenfabrik Augsburg Nürnberg."

The Argus Model III was built under license at the Nürnberg factory, while an engine of 185 h.p., which was quite similar to the 160-h.p. Mercedes design, was produced at the Augsburg plant. The latter did not produce sufficient power for the military requirements by the time that the quantity production stage was reached, so the cylinders were enlarged to make an over-dimensioned model with a performance corresponding to 260 h.p. at sea level.

At the Augsburg plant experiments were also made with a ten-cylinder engine estimated to deliver 350 h.p. at 1400 r. p.m. This engine had a direct driven propeller, and four valves per cylinder.

MANLY

The first successful airplane engine was designed by Chas. M. Manly in 1901 for Prof. Langley's experimental airplanes. With the possible exception of the Forest engine of 1888, it was also the first successful radial type engine. The Manly engine is now in the Smithsonian Institute at Washington. Considering the date of its design, together with the fact that the type was entirely new and the rotational speed very low, the weight per horsepower developed was remarkable. Many engines in use today do not show better weight-power proportions.

The Manly engine was a five-cylinder water-cooled radial type of 5 in. bore, 5.5 in. stroke, and 539.96 cu. in. total displacement. This engine developed 52.4 h.p. at 950 r.p.m. and weighed stripped 124 lbs., or 2.36 lbs. per h.p. With equipment the weight was said to be 151 lbs., or 2.88 lbs. per h.p. The total weight including radiator, gasoline tanks, and water was stated to be 192 lbs., or 3.66 lbs. per h.p.

The cylinders were drawn from steel plates and the walls machined to 1/16 in. thickness. Cast-iron liners were then pressed into place, the valve chamber forgings and the sheet-steel water jackets being brazed on. The cylinders were of

the "L" head type with valves one above the other. The inlet valves were overhead and operated automatically, while the exhaust valves were controlled by a single two-point cam rotating in the opposite direction to the crankshaft and at one-fourth of its speed.

Fig. 306. Longitudinal Section of the Manly Engine.

The connecting rods were of the slipper type, taper nuts being used to hold the assembly together. The master rod had a solid section, while the slipper rods were made with tubular sections. Ignition was provided by one spark coil

and vibrator, with a distributor to select the correct cylinder for firing. The spark plugs were of special design, and oil cups were provided for lubrication.

MARTIN

The Martin (Model 8200) airplane engine was an eight-cylinder water-cooled Vee type rated 190 h.p. at 1400 r.p.m. The bore was 4.625 in., the stroke 7 in., and the total displacement 940.8 cu. in. This engine was reported to weigh complete 484 lbs., or 2.54 lbs. per rated h.p.

Fig. 307. Rear End View of Martin Airplane Engine.

The cylinders were constructed entirely from steel, being made up in pairs with a common welded-on water jacket. Each cylinder had four inclined valves in the head which were operated by pull and push gear through double rocker arms from a single camshaft situated in the Vee. The crankshaft was supported on three plain bearings in an aluminum crankcase of the barrel type. The connecting rods were of the forked variety with "H" sections, and the pistons were made from aluminum.

Two carburetors situated in the Vee each supplied opposite pairs of cylinders. Lubrication was provided by independent pressure feed and splash systems, and the ignition was furnished by two magnetos having a detachable double distributor.

Fig. 308. Side View of Martin Airplane Engine.

MASSON

The Masson engine, which appeared during 1909 and 1910, was a six-cylinder air-cooled fan type in which all of the cylinders were placed above the horizontal center line. The valves in the cylinder head were operated by push rods, and inlet pipes radiated to the various cylinders from a crank-case compartment which was fed by a carburetor attached underneath. Two magnetos furnished the ignition. This engine was said to develop 50 h.p. and weigh 231 lbs., or 4.62 lbs. per rated h.p.

MAX AMS

During 1912, the Max Ams Machine Company marketed an eight-cylinder water-cooled Vee type engine rated at 75 h.p. The bore was 3.9375 in., the stroke 5.125 in., and the total displacement 353.36 cu. in. The dry weight, including equipment, was stated to be 315 lbs., or 4.2 lbs. per rated h.p. The cylinders were of cast-iron construction, Mea magnetos supplied the ignition, and a force feed system of lubrication was used. The approximate overall dimensions were as follows: length 41 in., width 34 in., and height 31 in.

MAXIM

The Maxim engine was a four-cylinder vertical water-cooled type rated 87 h.p. at 1400 r.p.m. The bore was 5 in.,

the stroke 5.625 in., and the total displacement 441.8 cu. in. This engine was reported to weigh 220 lbs., or 2.53 lbs. per rated h.p.; and the fuel consumption was stated to be .6 lbs. per h.p-hr.

The carburetors were of special design, and forced lubrication was provided by a piston pump. The individual cylinders were constructed of steel and fitted with German silver water jackets.

Fig. 309. The Maxim Four-Cylinder Engine.

MAXIMOTOR

The Maximotors were built by Mr. Max Dingfelder at Detroit, Michigan.

A-4. The Maximotor Model A-4 was a four-cylinder vertical water-cooled engine of 4.5 in. bore, 5 in. stroke, and 318 cu. in. total displacement. It was rated 50 h p. at 1200 r.p.m., and said to weigh 210 lbs., or 4.2 lbs. per rated h.p.

A-6. The A-6 type employed the same cylinders as the model A-4 and therefore had a total piston displacement of 477 cu. in. This engine was rated 75 h.p. at 1200 r.p.m., 85 h.p. at 1600 r.p.m., and was said to weigh 340 lbs.

A-8. The Model A-8 engine was an eight-cylinder 90 degree Vee type rated 110 h.p. at 1350 r.p.m. and 115 h.p. at 1600 r.p.m. The cylinders were of the same dimension as the A-4 and A-6 models, therefore the total displacement was 636 cu. in. The weight was reported to be 420 lbs.

B-6. The Maximotor Model B-6 engine was a six-cylinder vertical water-cooled type of 5 in. bore, 6 in. stroke, and 706.86 cu. in. total displacement, that was rated 115 h.p. at 1600 r.p.m. The weight was reported to be 385 lbs., or 3.55 lbs. per rated h.p.

A Maximotor four-cylinder vertical water-cooled type, rated at 70 h.p., had a 5.25 in. bore, 5.5 in. stroke, and a total displacement of 476.24 cu. in. The total weight was said to be 215 lbs , or 3.15 lbs. per rated h.p. This engine was equipped with Kingston carburetors and Mea magnetos, and employed a forced-feed system of lubrication. The cylinders were of semi-steel construction. The overall dimensions were as follows: length 41 in., width 16 in., and height 29 in.

Fig. 310. The Maximotor Model A-8 Engine.

MAYBACH

The Maybach engines, constructed by the Canstatt-Daimler Company, are six-cylinder vertical water-cooled types following usual characteristic German form of construction. The 200-h.p. model was used exclusively in the Zeppelin, Schütte-Lanz, and Parseval airships; and during the war the 300-h.p. type was developed for airplane use, several having been captured in Rumpler C4 and 5 type airplanes.

One of the early Maybach engines, rated 180 h.p. at 1200 r.p.m., had a 160 mm (6.3 in.) bore, 170 mm. (6.69 in.) stroke,

and a total displacement of 1251.24 cu. in. The fuel consumption was stated to be .51 lbs. per h.p-hr., and the oil consumption .025 lbs. per h.p-hr. The weight was reported to be 990 lbs., or 5.5 lbs. per rated h.p. Cylinders of the "T" head type were constructed of cast iron.

The airship power unit, which was rated 200 h.p. at 1200 r.p.m., had a 150 mm. (5.91 in.) bore, 190 mm. (7.48 in.) stroke, and a total displacement of 1228.8 cu. in. The compression ratio was 5.94 to 1.

The cylinders consisted of steel barrels screwed into malleable-iron heads with integral side jackets which were packed at the lower end. Each individual cylinder was fitted with five vertical valves in the cylinder head, two inlets of 48 mm. (1.89 in.) diameter and 9.3 mm. (.366 in.) lift, and three exhaust valves of 35 mm. (1.38 in.) diámeter and 7.88 mm. (.31 in.) lift. A push rod on each side operated the inlet and exhaust valves of each cylinder by single rocker arms. A large circular water joint between each cylinder was made tight by a rubber ring encircled by a band clip of sheet brass.

The crankshaft was a six-throw type supported in seven plain bearings with separate caps, and the connecting rods had square sections which were bored out. The pistons were made of cast iron and employed three top rings. The piston pin was locked in the piston and the bearing was lubricated by oil from the crankpin led through a pipe carried within the hollow section of the connecting rod. A special arrangement for breathing and scavenging the crank compartment consisted of seven gauze covered ventilators on one side of the case and corresponding openings on the opposite side which communicated to a marine-type cowl.

The two water-jacketed carburetors were attached to the end cylinders at the water jacket flanges. These carburetors consisted of a barrel throttle, a main air regulator, a jet, and damping device; and a constant head gravity fuel feed reservoir. The carburetors and fuel feeding device were of unique design, this particular feeding device being unaffected by variation in altitude.

The lubricating system was a very complete and carefully worked-out design employing piston type oil pumps. The engine was equipped with a mechanical self-starter, and

dual ignition was provided by two Bosch ZH6 magnetos.

The airplane engine, generally referred to as the 300-h.p. Maybach, developed 283 h.p. at 1400 r.p.m. and 302 h.p. at 1700 r.p.m. The bore was 165 mm. (6.5 in), the stroke 180 mm. (7.09 in.), and the total displacement 1411.62 cu. in. The compression ratio was 5.91, and the maximum brake mean effective pressure which occurred at 1000 r.p.m., was 123 lbs. per sq. in. The fuel consumption was reported to be .464 lbs. per h.p-hr., the oil consumption .0223 lbs. per h.p-hr. The dry weight was said to be 921 lbs., and the water content of the engine 22 lbs.

Fig. 311. The 300-h.p. Maybach Engine.

The design was similar in many respects to the 200-h.p. airship engine. The cylinder heads, which were cast from iron, received the screwed-in steel cylinder barrels, but the water jackets were separately machined inside and out to a very thin wall from steel forgings and fastened to the head by threads and by a packing nut at the lower end to the cylinder barrel. There were four vertical valves in each cylinder, with a port diameter of 48 mm. (1.89 in.), 30 degree seats, and a lift of .375 in. The valve ports were siamesed. The inlet valve opened 8 degrees early and closed 35 degrees late; the exhaust

F

tl

Fig. 314. Longitudinal Section of 300-h.p. Maybach Engine.

valve opened 33 degrees early and closed 7 degrees late. There were two water connections between the heads of adjacent cylinders instead of the large diameter flanges employed on the 200-h.p. model.

The crankshaft, connecting rods, and pistons were very similar to those used in the smaller engine. Two Maybach carburetors, of 2.44 in. diameter and mounted at the water flanges of the end cylinders, fed into a manifold which had a baffle plate at the center. Crankcase ventilation was again very carefully worked out.

The former Maybach oil plunger pumps were replaced by three pumps of the gear type. Oil was fed to the main bearings under pressure through diagonally drilled holes in the upper crankcase from external connections. The fuel pump was an opposed plunger type driven by an eccentric which operated in a chamber under oil pressure. Dual ignition was furnished by two Bosch ZH6 magnetos.

The Maybach efforts in building extremely large six-cylinder vertical types was an engine of 200 mm. (7.87 in.) bore, 240 mm. (9.45 in.) stroke, and 2758.18 cu. in. total displacement. The cylinders each had four valves of 62 mm. (2.44 in.) diameter, and the compression ratio was 6.07. In spite of the addition of a 110 lb. flywheel, the vibration proved to be severe for the crankcase.

Fig. 315. The McDowell Twin-Piston Engine.

McDOWELL

The McDowell twin-piston engine was designed and built by Mr. Geo. McDowell of Brooklyn, N. Y. This was a four-cylinder water-cooled Vee type which operated on the two-stroke cycle.

MEAD

During 1912, the Mead Engine Company of Dayton, Ohio, built a four-cylinder vertical water-cooled engine rated at 50 h.p. The bore was 4.75 in., the stroke 4.5 in., and the total displacement 301.24 cu. in. The total dry weight of the engine was stated to be 250 lbs., or 5 lbs. per rated h.p.

The cylinders were made from cast iron and employed rotary type valves. Mea magnetos furnished the ignition, and a force-feed system of lubrication was used. The approximate overall dimensions were as follows: length 33 in., width 19.5 in., and height 31 in.

MERCEDES

The Mercedes airplane engines, which have been frequently referred to as the German-Daimler or Mercedes-Daimler designs, were built at Stuttgart, and are probably the best known of any of the German makes. These engines came into prominence during 1913, and during the war were one of the standard types adopted by the Germans. Water-cooled vertical engines of four, six, and eight cylinders were the types constructed.

The first Mercedes engine was a four-cylinder vertical water-cooled type rated at 50 h.p. The overhead valves were operated by push rods and rockers, and the timing gears were not enclosed. A similar design, rated 60 h.p. at 1350 r.p.m., had a 110 mm. (4.33 in.) bore, 140 mm. (5.51 in.) stroke, and 324.56 cu. in. total displacement.

Type E4F. The four-cylinder vertical Mercedes engine with 120 mm. (4.72 in.) and 140 mm. (5.51 in.) bore and stroke, and a total displacement of 385.64 cu. in., was rated at 70 h.p. The engine actually developed 60 h.p. at 1200 r.p.m. and 70 h.p. at about 1350 r.p.m., and was said to consume on an average .53 lbs. of fuel per h.p-hr. and .033 lbs. of oil per

h.p-hr. The weight was reported to be 308 lbs., or 4.4 lbs. per rated h.p.

The cylinders were originally cast in pairs from grey iron with water jackets integral. Later the jackets were made separately from sheet steel and welded in place. The connecting rods had "H" sections, and the pistons were made from pressed steel. Dual ignition was supplied by Bosch magnetos.

A similar four-cylinder vertical design of 140 mm. (5.51 in.) bore, 150 mm. (5.91 in.) stroke, and 563.68 cu. in. total displacement, developed normally 90 h.p. at 1200 r.p.m. and 100 h.p. at 1400 r.p.m. The fuel consumption was said to be .49 lbs. per h.p-hr., and the weight 400 lbs., or 4.44 lbs. per normal h.p.

Fig. 316. The Four-Cylinder Inverted Mercedes Engine.

Type J4L. A four-cylinder Mercedes engine, known as Type J4L, had a 160 mm. (6.3 in.) bore, 170 mm. (6.69 in.) stroke, and a total displacement of 834.16 cu. in. This engine was rated 120 h.p. at 1100 r.p.m., and said to weigh 660 lbs., or 5.5 lbs. per rated h.p. The consumption of fuel and oil was reported as .53 and .033 lbs. per h.p-hr., respectively. The cylinders were constructed in pairs from cast-iron, and one inlet and two exhaust valves, standing vertically in each cylinder head, were operated by means of push rods and rockers.

A four-cylinder engine, having the same rating and approximately the same weight as the J4L type, was designed principally for dirigible use. The bore was 175 mm. (6.89 in.), the stroke 165 mm. (6.5 in.), and the total displacement 969.4 cu. in.

Fig. 317. Exhaust Side of Mercedes 100-h.p. Engine.

Inverted Type. As a means of affording greater visibility to the pilot, a four-cylinder unit was built with Type E4F cylinders extending vertically downward. This engine was also said to develop 70 h.p. at 1400 r.p.m. Aside from the over-oiling which might possibly be anticipated with such an arrangement, the practical results obtained are identical with engines having cylinders placed above the crank compartment. For water circulation, the inverted cylinders offer the advantage of entering the cooled water from the radiator directly upon the combustion head which is the hottest part of the cylinder.

Type J8L. An eight-cylinder vertical engine, employing the same cylinders as the J4L type, was rated 240 h.p. at 1100 r.p.m. The total displacement was 1668.32 cu. in., and the weight was said to be 1250 lbs., or 5.22 lbs. per rated h.p.

Another eight-cylinder engine, rated 240 h.p. at 1100 r. p.m., was said to weigh 1820 lbs., or 7.58 lbs. per rated h.p.

This engine was intended for dirigible use. The bore was 175 mm. (6.89 in.), the stroke 165 mm. (6.5 in.), and the total displacement 1938.8 cu. in.

During recent years the Mercedes designs have been confined almost entirely to the six-cylinder vertical water-cooled

Fig. 318. Inlet Side of Mercedes 100-h.p. Engine.

types. One of the earlier six-cylinder engines, that developed 80 h.p. at 1200 r.p.m. and 90 h.p. at 1400 r.p.m., had a 105 mm. (4.13 in.) bore, 140 mm. (5.51 in.) stroke, and a total displacement of 442.86 cu. in. The fuel consumption was said to be .505 lbs. per h.p-hr., and the total weight 312 lbs.

Type E6F. The type E6F was one of the first Mercedes engines to employ an overhead camshaft and the valve gear which has proven so popular. This engine was rated at 100 h.p. and said to weigh 444 lbs. The bore was 120 mm. (4.72 in.), the stroke 140 mm. (5.51 in.), and the total displacement 578.46 cu. in. The fuel and oil consumption were reported as .53 and .033 lbs. per h.p-hr., respectively.

160-h.p. Model. The 160-h.p. Mercedes engines were used in large numbers by the Germans from the very beginning of the war. These were six-cylinder vertical water-cooled engines of 140 mm. (5.51 in.) bore, 160 mm. (6.3 in.) stroke, and 901.32 cu. in. total displacement. The actual out-

Fig. 319. Longitudinal Section of Mercedes 160-h.p. Engine.

put at the normal speed of 1400 r.p.m. was 162.5 h.p. The compression ratio was 4.5, and the maximum brake mean effective pressure 109 lbs. per sq. in. occurred at 1100 r.p.m. The total weight was said to be 618 lbs., or 3.86 lbs. per rated h.p.

The cylinders were machined individually from steel forgings; the valve ports were screwed and welded to the cylinder head, and the whole assembly encased in sheet-steel water jackets. Inclined valves, of 68 mm. (2.67 in.) clear diameter and 11:25 mm. (.44 in.) lift, were operated from an overhead camshaft by rocker arms. The rocker arms worked through slots in the malleable-iron camshaft casing and were provided with felt packing strips and baffle plate for retaining the oil. The valve timing was as follows: the inlet opened 2 degrees late and closed 35 degrees late; the exhaust opened 63 degrees early and closed 13 degrees late. A half-compression gear was provided for starting purposes.

Fig. 320. Transverse Section of Mercedes 160-h.p. Engine.

The six-throw camshaft was supported in seven plain bearings, the bearing caps being formed integral with both upper and lower halves of the crankcase. The crankcase was made from aluminum and the long bearing bolts which held the halves together were also used for holding down the cylinders. The connecting rods had "H" sections and caps held in place by two bolts. The piston was formed by screwing and welding a cast-iron skirt upon a forged-steel head that was integral with the piston pin bosses.

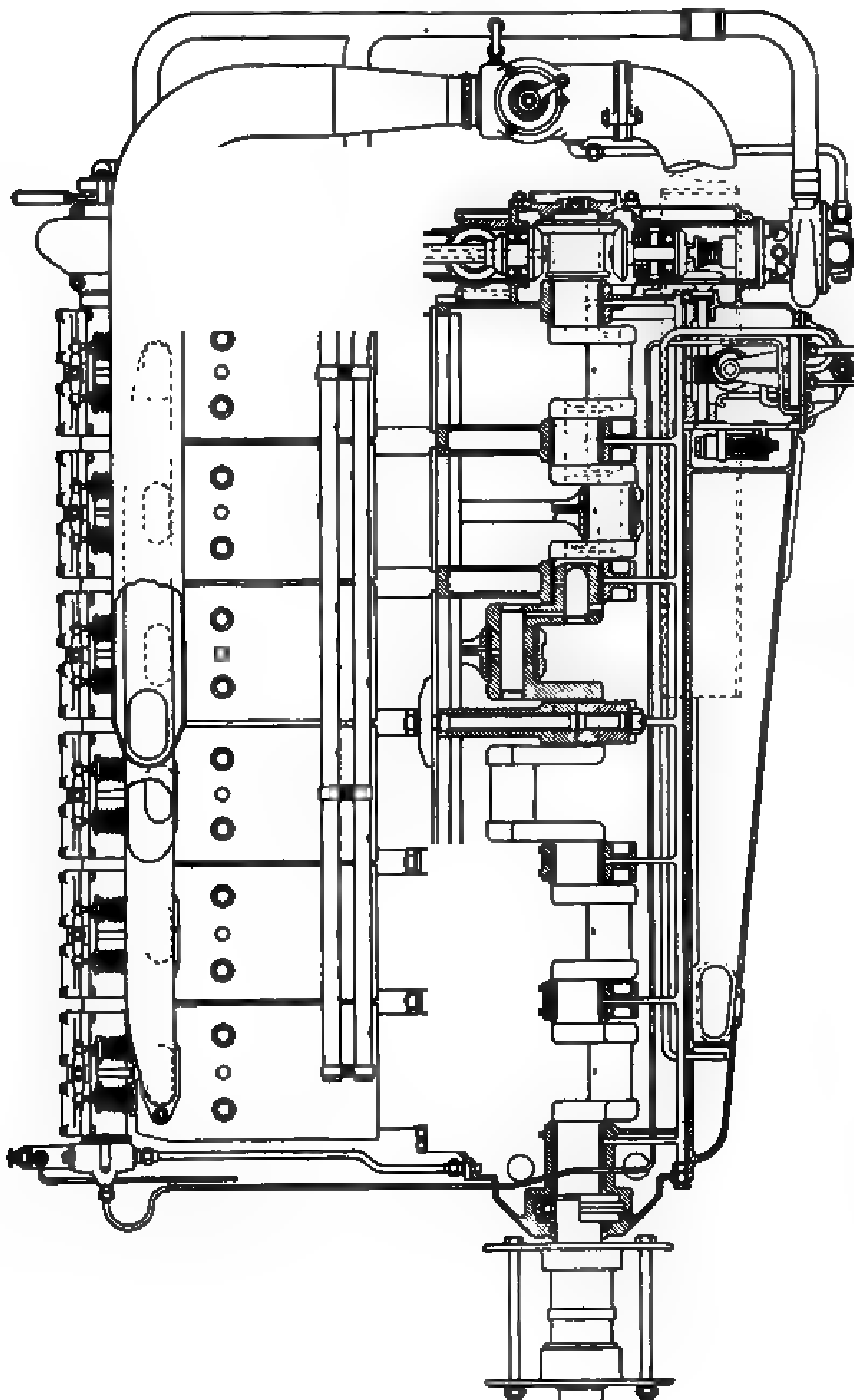


Fig. 321. Longitudinal Section of Mercedes 260-h.p. Engine.

The fuel consumption was said to be .522 lbs. per h.p-hr., and the oil consumption .035 lbs. per h.p-hr. Two Mercedes designed carburetors supplied the mixture, and the oil was delivered to the working parts under pressure by a specially designed plunger pump. Dual ignition was provided by Bosch Type ZU-6 magnetos.

240-h.p. Model. The Germans for a time used some eight-cylinder vertical engines with cylinders common to the 160-h.p. model. The compression ratio was increased to 4.73, and a spur gear propeller reduction with a ratio of approximately .725 gave the propeller a normal speed of 980 r.p.m. The total displacement was 841.76 cu. in., and at 1100 r.p.m., 119.5 lbs. per sq. in. maximum b.m.e.p. was developed. The output at normal engine speed (1350 r.p.m.) was 242 h.p., and at the maximum recommended speed of 1750 r.p.m., 287 h.p. was developed. The total weight, including exhaust manifolds, was 900 lbs., or 3.75 lbs. per rated h.p.

The cylinder, pistons, and connecting rods were the same as used in the 160-h.p. engine. The inlet valve lift was 11.4 mm. (.45 in.) and the exhaust valve lift 10.48 mm. (.412 in.). The valve timing was as follows: the inlet opened 2 degrees late and closed 51 degrees late; the exhaust opened 52 degrees early and closed 16.5 degrees late. The eight-throw crankshaft was made in one piece and supported in nine plain bearings. The crank webs were progressively increased in thickness toward the propeller end.

The fuel consumption ranged from .524 to .582 lbs. per h.p-hr., and the oil consumption from .042 to .047 lbs. per h.p-hr. Two Mercedes twin-jet carburetors furnished the mixture, and two Bosch HL8 magnetos dual ignition. Forced lubrication was delivered by a multiple plunger pump.

260-h.p. Model. The 260-h.p. Mercedes engine in many respects resembled the 160-h.p. design. There were six vertical water-cooled cylinders of 160 mm. (6.3 in.) bore, 180 mm. (7.09 in.) stroke, and 1326.06 cu. in. total displacement. The compression ratio was 4.94. The engine delivered 252 h.p. at a normal speed of 1400 r.p.m., and weighed complete 936 lbs., or 3.9 lbs. per rated h.p. The length over the propeller hub was 77.5 in. and the overall height 46 in.

Steel cylinder barrels were screwed and welded into forged-steel dome-shaped cylinder heads upon which had been welded two double valve ports of similar material. The sheet-steel water jackets in four sections were welded in place. The valves were inclined to the vertical axis and operated by a T shaped rocker arm from an overhead camshaft that was supported by seven phosphor-bronze bearings in a malleable-iron

Fig. 322. Inlet Side of Mercedes 260-h.p. Engine.

housing. The valve gear design was improved over that of the 160-h.p. model. The valve ports were siamesed, the four valves of 55.25 mm. (2.175 in.) clear diameter being interchangeable. The inlet valve lift was 10.125 mm. (.3986 in.) and the exhaust valve lift 10 mm. (.3937 in.). The valve timing was as follows: the inlet opened 1 degree late and closed 49 degrees and 3 minutes late; the exhaust opened 50 degrees

and 36 minutes early and closed 17 degrees and 36 minutes early. The half-compression cam opened 12 degrees after bottom center and closed 44 degrees before top center.

The six-throw crankshaft was supported in seven plain bearings, and the connecting rods had "H" sections and four-bolt caps. The piston had a forged-steel head and a cast-iron skirt similar to the 160-h.p. design, and was fitted with three top rings and one lower oil scraper ring.

Fig. 323. Exhaust Side of Mercedes 260-h.p. Engine.

A twin jet Mercedes carburetor, situated at the rear, fed into a large six-cylinder manifold. The fuel consumption was stated to be .541 lbs. per h.p-hr. Forced lubrication was provided by an eccentric driven plunger pump which added a certain quantity of fresh oil to the system. Dual ignition was supplied by two Bosch ZH-6 magnetos.

180-h.p. Model. The 180-h.p. Mercedes engine is an improved 160-h.p. model with a number of the 260-h.p. design features incorporated. The cylinders are similarly constructed and have the same bore and stroke, but the compression ratio has been raised from 4.5 to 4.64. Under test this engine developed 174 h.p. at a normal speed of 1400 r.p.m. The dry weight is reported to be 635 lbs., or 3.52 lbs. per rated h.p.

The crankshaft and connecting rods are practically identical to those of the 160-h.p. engine. The valve gear, although similar in many respects, has been greatly improved. The rockers no longer work through a slot, the design now being a close copy of Loomis valve gear that was used on the Liberty. The vertical camshaft driveshaft is of new design, a water pump similar to the 260-h.p. design now being placed below the engine at the end opposite the propeller.

The valve timing is changed to the following: the inlet opens on top center and closes 40 degrees late; the exhaust opens 40 degrees early and closes 10 degrees late. The lift of both valves is 11.5 mm. (.453 in.). The oil pump has been changed to one similar in design to the 260-h.p. engine pump. The fuel consumption is said to be .472 lbs. per h.p-hr., and the oil consumption .047 lbs. per h.p-hr.

A 650-h.p. model, patterned after the 260-h.p. Mercedes design, had a normal speed of 1250 r.p.m. and weighed 2315 lbs. The bore was 235 mm. (9.25 in.), the stroke 250 mm. (9.84 in.), and the total displacement 3967.49 cu. in. In each cylinder were four valves of 90 mm. (3.54 in.) diameter. During the tests, severe vibration resulted in the failure of the crankcase.

Experiments carried on with an eighteen-cylinder W type engine were also unsuccessful.

MÉTALLURGIQUE

The Métallurgique engines were four-cylinder vertical water-cooled types produced in France during 1910. The smaller engine was rated 32 h.p. at 1850 r.p.m., and reported to weigh 300 lbs., or 9.4 lbs. per rated h.p. The bore was 100 mm. (3.94 in.), the stroke 150 mm. (5.91 in.), and the total displacement 288.24 cu. in.

A larger four-cylinder model was rated 49 h.p. at 1600 r.p.m. This engine was stated to weigh 550 lbs., or 11.2 lbs. per rated h.p. The bore was 125 mm. (4.92 in.), the stroke 152 mm. (5.98 in.), and the total displacement 454.76 cu. in.

METZ

The Metz Co. of Waltham, Massachusetts, produced a seven-cylinder air-cooled rotary engine rated 125 h.p. at 800

r.p.m. This engine had a bore and stroke of 6.75 in., and a total displacement of 1690.85 cu. in. The dry weight was reported to be 375 lbs., or 3 lbs. per rated h.p.

The steel cylinders had integral cooling fins and valves in the cylinder head operated by means of push rods. The crankcase was an aluminum casting, and the crankshaft was made hollow for the purpose of feeding fuel and oil into the crank compartment, where it could be distributed by centrifugal force.

Fig. 325. The Metz Rotary Engine.

MICHIGAN

A two-cylinder air-cooled rotary engine, known as the Michigan, was designed and built experimentally by Mr. Fred Weinberg of Detroit, during 1911. This engine had a 5 in. bore and stroke, and a total displacement of 196.35 cu. in.

Both cylinders fired simultaneously during each revolution. The engine operated on the two-stroke cycle and was fitted with an independent exhaust valve. The gas was drawn through the hollow crankshaft and prevented from escaping on the return stroke of the pistons by a check valve placed be-

tween the carburetor and crank compartment. The charge entered the cylinders through a by-pass when the pistons were down.

The valves had no springs. They were held to their seats by centrifugal force, and operated by means of push rods and rockers. The cylinders and pistons were made from cast iron, and a magneto, driven at the same speed of the cylinders, provided ignition.

MIESSE

The Miesse was an eight-cylinder water-cooled radial engine built during 1909. It was rated 100 h.p. at 1200 r.p.m. and reported to weigh 245 lbs., or 2.45 lbs. per rated h.p. The bore and stroke were 130 mm. (5.12 in.), and the total displacement 842.72 cu. in.

MILLER

The Harry A. Miller Manufacturing Company of Los Angeles, California, manufacturers of racing automobile engines and carburetors, have constructed two types of airplane engines. The smaller engine was a four-cylinder vertical water-cooled type, rated normally at 125 h.p. and said to have developed 139 h.p. at 2600 r.p.m. and 155 h.p. at 2900 r.p.m. The bore was 4 in., the stroke 7 in., and the total displacement 351.84 cu. in. A reduction gear, having a ratio of .54 and giving the propeller a normal speed of 1350 to 1400 r.p.m., was employed.

Completely machined vanadium cast-iron cylinder sleeves were inserted in the water jackets and packed with rubber ring gaskets. The cylinder head, that rested upon the sleeves and held them in place, was cast from aluminum alloy and contained cast-iron valve seats cast into place. The water jacket around the cylinder barrels was cast as an integral part of the crankcase.

The crankshaft was made in two parts, the joint being made at the center with a taper, key, and nut. The shaft was counterbalanced and carried in three annular double-row ball bearings. The connecting rods had tubular sections, four-bolt caps, and wrist pins clamped in the upper ends.

Fig. 326. Inlet Side of Miller Engine.

There were four valves per cylinder, the valve mechanism being completely enclosed and operating in a bath of oil. The camshaft, which was driven by a train of spur gears, was composed of four cam units and five annular ball bearings mounted on a tubular shaft. Each cam unit comprised an inlet and exhaust cam with their followers. The follower cam caused the rocker to follow the main cam and thereby gave a positive movement to the rocker.

The pistons were made from aluminum and fitted with two rings. The reduction gear was of the planetary type, double-row annular ball bearings being used throughout in

Fig. 327. Exhaust Side of Miller Engine.

its mounting. Dual ignition was provided by two individual magnetos, and the lubricating system was of the dry sump type with a gear pump to circulate the oil. The dry weight was reported to be 410 lbs., or 3.28 lbs. per rated h.p. The overall dimensions were as follows: length 41 in., width 18.25 in., and height 34 in.

A twelve-cylinder 60 degree Vee type water-cooled Miller engine, corresponding in general arrangement to the Duesenberg and Lancia designs, had a 5 in. bore, 6 in. stroke, and a total displacement of 1413.72 cu. in. Twelve vanadium cast-iron sleeves were inserted into a single aluminum block in a similar manner to the 125-h.p. model. The valves were situated horizontally in respect to the cylinder axis and operated through rockers from a single camshaft in the Vee. The valves had a clear diameter of 2.25 in. and a .5 in. lift.

The aluminum pistons were fitted with three top rings, and the crankshaft was of the seven-bearing type. Four 1¾ in. Miller carburetors supplied the mixture, and two Dixie twelve-cylinder magnetos the ignition. Lubrication was of the dry sump type, one set of gears being used to force oil to the bearings under pressure, and two sets to scavenge the sump.

Fig. 328. The Six-Cylinder Mulag Engine.

MORS

The Mors was a four-cylinder Vee type water-cooled engine built during 1910. The bore was 100 mm. (3.94 in.), the stroke 130 mm. (5.12 in.), and the total displacement 249.68 cu. in. This engine was rated 30 h.p. at 1700 r.p.m., and stated to weigh 213 lbs., or 7.1 lbs. per rated h.p.

MULAG

A six-cylinder vertical water-cooled Mulag engine, entered in the German engine trials of 1913, was rated 90 to 113 h.p. at 1346 r.p.m. The bore was 110 mm. (4.33 in.), the stroke 170 mm. (6.69 in), and the total displacement 591.06 cu. in. The weight was said to be 482 lbs. The overall dimensions were quite large, due to the crankshaft extension, and a very deep sump. The valve springs and tappets were inclosed by telescopic aluminum tubes serving as vents.

MURRAY-WILLAT

The Murray-Willat Company built their first valveless rotary engine during 1910. These engines operated on the two-stroke cycle. A blower, integrally incorporated in the engine, compressed the air and forced fuel into the engine for the purpose of improving the performance at altitude. At the bottom of each cylinder were open exhaust ports which permitted complete scavenging, and the blowing of a blast of fresh air across the piston at the end of each stroke.

The cylinders were turned from forged-steel billets. In addition to the large exhaust ports, there were small inlet ports that registered with deflectors provided on each side at the top of the piston. These directed the charge toward the top of the cylinder and thus prevented it from escaping through the exhaust ports before the piston had closed all ports on its upward stroke.

The crankcase was machined from solid steel forgings, the two halves clamping the cylinders in place between them. The connecting rods were mounted in a spool that was carried on two ball bearings. The crankshaft was made hollow for the purpose of providing a passage for the gas mixture from the blower into the crankcase where a pressure of 7 lbs. was maintained. Ignition was provided by a magneto.

Fig. 329. The Murray-Willat 90-h.p. Model.

Following the experimentation with this type of engine, the Murray-Willat Company built two six-cylinder models. The smaller engine, which was rated 35 h.p. at 1200 r.p.m., had a 75 mm. (2.95 in.) bore, 90 mm. (3.54 in.) stroke, and a total displacement of 145.68 cu. in. The gasoline consumption was said to be .615 lbs. per h.p-hr,. and the oil consumption 2.8 lbs. per hr. The overall diameter was 25.98 in., and the weight was reported to be 132.3 lbs , or 3.8 lbs. per rated h.p.

A larger model, rated 90 h.p. at 1200 r.p.m., had a 100 mm. (3.94 in.) bore, 130 mm. (5.12 in.) stroke, and a total displacement of 374.52 cu. in. The gasoline consumption was said to be .411 lbs. per h.p-hr., and the oil consumption 2.3 lbs. per hr. The outside diameter was 29 in., and the complete weight was said to be 260 lbs., or 2.88 lbs. per rated h.p.

N. A. G.

The N. A. G. engines were built by the Neue Automobil Gesellschaft in Germany during 1912 and later.

Fig. 330. Inlet and Exhaust Side of N. A. G. F-2 Engine.

F-1. The N. A. G. Model F-1 engine was a four-cylinder vertical water-cooled type of 118 mm. (4.65 in.) bore, 100 mm. (3.94 in.) stroke, and 267.64 cu. in. total displacement. This engine was rated 55 h.p. at 1600 r.p.m., and was said to weigh 211 lbs., or 3.83 lbs. per rated h.p.

Fig 331. The N. A. G. Model F-2 Four-Cylinder Engine.

F-2. The N. A. G. F-2 engine was a four-cylinder vertical water-cooled type of 120 mm. (4.72 in.) bore and stroke, and a total displacement of 330.36 cu. in. This engine was rated 55 h.p. at 1400 r.p.m. and 60 h.p. at 1600 r.p.m. The weight was reported to be 212 lbs.

The cast-iron cylinders had copper water jackets held in place by spring rings and were mounted to one side of the crankshaft center line. The valves in the cylinder head were operated by means of push rods and rockers. Lubrication was of the force-feed type, and the ignition was furnished by a magneto. A compression release was employed for starting purposes.

Fig. 332. Inlet and Exhaust Side of N. A. G. F-3 Engine.

F-3. The N. A. G. Model F-3 engine was a four-cylinder vertical water-cooled type rated 100 h.p. at 1250 r.p.m. The bore was 135 mm. (5.31 in.) the stroke 165 mm. (6.5 in.), and the total displacement 575.76 cu. in. The fuel consumption was reported to be .473 lbs. per h.p-hr. The total weight was said to be 353 lbs., or 3.53 lbs. per rated h.p.

F-4. The N. A. G. F-4 type was a six-cylinder vertical water-cooled engine rated 150 h.p. at 1250 r.p.m. The cyl-

Fig. 333. The N. A. G. Model F-3 100-h.p. Engine.

inders were of the same dimensions as the F-3 model, therefore the total displacement was 863.64 cu. in. The crankshaft

Fig. 334. Inlet and Exhaust Side of N. A. G. F-4 Engine.

Fig. 335. The N. A. G. Model F-4, 150-h.p. Engine.

was mounted in seven plain bearings, and ignition was supplied by two magnetos. The dry weight, with one magneto and no flywheel, was said to be 507 lbs., or 3.38 lbs. per rated h.p.

Fig. 336. The Model 301 N. A. G. Engine.

Model 301. A six-cylinder vertical water-cooled engine for dirigible use was rated 110 h.p. at 1100 r.p.m. and 120 h.p. at 1300 r.p.m. The bore was 150 mm. (5.91 in.), the stroke 130 mm. (5.12 in.), and the total displacement 842.7 cu. in. The consumption of fuel was said to be .473 lbs. per h.p-hr. Magneto ignition was employed; and the complete weight, including the flywheel, was reported to be 770 lbs., or 6.42 lbs. per rated h.p.

Fig. 337. Inlet Side of 185-h.p. N. A. G. Engine.

Fig. 338. Timing End of 185-h.p. N. A. G. Engine.

Fig 339. Propeller End of 185-h.p. N. A. G. Engine.

A larger six-cylinder vertical water-cooled N. A. G. engine, rated at 185 h.p., was developed later.

NAPIER

D. Napier and Son, Ltd., of Acton Vale, London, W.3, England, brought out a "W" type airplane engine, known as the "Lion," during the latter part of the war. It was accepted by the British Air Ministry, but not in time to be put into effective service at the Front. The "Lion" engines have given a rather remarkable performance, and are now looked upon very favorably by most British pilots. Mr. Rowledge, chief designer of the Napier Company before joining Rolls-Royce, brought out an unusual "X" type engine, known as the "Cub," which develops over 1000 h.p.

"Lion." The twelve-cylinder Napier "Lion" engine is a "W" type formed in three rows of four cylinders each with an included angle of 60 degrees between the vertical and each outer row. The bore is 5.5 in., the stroke 5.125 in., and the total displacement 1461.6 cu. in. The compression ratio is 5.53 to 1. The engine is rated normally 450 h.p. at 1925 r.p.m. and develops approximately 500 h.p. at 2050 r.p.m. The normal brake mean effective pressure is approximately 127 lbs. per sq. in. The propeller is driven through plain type spur reduction gears having a ratio of .66.

When run with fuel containing 20 per cent benzol, a consumption of .504 lbs. per h.p-hr. is ordinarily obtained. Castor oil is used for lubrication, the consumption being .037 lbs. per h.p-hr. Single and duplex types H-C-7 Claudel carburetors, having water-jacketed throttles, are fitted. Lubrication is of the dry sump type, one pressure and two scavenging gear pumps circulating the oil. A normal oil pressure of 45 to 50 lbs. is maintained at the bearings.

The cylinders are arranged in blocks of four, each block being composed of a single head casting carrying in its upper portion, the two camshafts with their bearings, the driving bevel and spur gears, together with the valve tappets and compression release cam mechanism. The lower portion of the casting contains the inlet and exhaust ports and forms the upper part of the water space. The cylinder barrels are machined separately from steel forgings and attached to the

cylinder head by screwed-in thimbles which serve as valve seats. Sheet-metal water jackets are separately welded around each cylinder barrel.

There are two inlet and two exhaust valves per cylinder, the two inlet valves having a .344 in. lift and a total opening area of 3.55 sq. in., and the two exhaust valves a .354 in. lift and a total opening area of 3.65 sq. in. The valve timing is as follows: the inlet opens 10 degrees late and closes 51 degrees late; the exhaust opens 48 degrees early and closes 10 degrees late. The cams operate directly upon the valves, the adjustment for clearance being arranged quite similar to Hispano-Suiza practice.

Fig 340. Transverse Section of Napier "Lion" Engine.

The crankshaft is a four-throw type mounted in five roller bearings, and one plain bearing which is just outside the driving gear at the propeller end. The connecting rods are of the articulated type, the forked sections for the articulated rods appearing on the master rod which is in the center. The master rod has an "H" section, and the articulated rods have

tubular sections. Internally ribbed aluminum pistons are fitted with three top rings and one bottom ring, the lower two being used as oil scrapers.

The cooling water is circulated by a centrifugal pump having three outlets, separate water connections being made to the jackets surrounding the cylinder barrel and to the cylinder head casting. Dual ignition is furnished by two twelve-cylinder Thompson-Houston magnetos (Type AV-12), one of these units having a special distributor rotor to be used in connection with a starting magneto. The weight is said to be 858 lbs., or 1.9 lbs. per rated h.p. The approximate overall dimensions are as follows: length 49.5 in., width 41.875 in., and height 36 in.

Fig. 341. Longitudinal Section of Napier "Lion" Engine.

"Cub." The Napier "Cub" is a water-cooled sixteen-cylinder X type engine of 6.25 in. bore, 7.5 in. stroke, and 3681.6 cu. in. total displacement. It is rated normally 1000 h.p. at 1800 r.p.m., the propeller gear reduction having a ratio approx-

Fig. 342. The Napier "Lion" 450-h.p. Engine.

imately .418. The compression ratio is 4.5, and the normal brake mean effective pressure nearly 120 lbs. per sq. in. The

Fig. 343. Propeller End of Napier "Cub" Engine.

fuel consumption is said to be .495 lbs. per h.p-hr., and the weight approximately 2240 lbs., or 2.24 lbs. per rated h.p.

The separate cylinders are of built-up steel construction and have four valves inclined normally to the dome-shaped combustion chamber and operated by an overhead camshaft through rockers. Ignition is by four B. T. H. magnetos or Delco battery system. Double choke Napier with Claudel-Hobson diffuser carburetors are cast upon the oil sump. The roller bearing crankshaft and propeller reduction gears correspond in design to those used in the "Lion" engine. The angle between the upper rows of cylinders is 52.5 degrees and between the lower rows it is 127.5 degrees, hence the upper and lower cylinders on either side form a 90 degree Vee.

Fig. 344. The Napier "Cub" Engine.

N. E. C.

The two-cycle N. E. C. engines, built in England by the New Engine Company during 1910, were largely in British Wright machines. A four-cylinder vertical air-cooled model, rated 70 h.p. at 1500 r.p.m., had a 114 mm. (4.48 in.) bore, 101

mm. (3.98 in.) stroke, and a total displacement of 250.96 cu. in. The weight was said to be 290 lbs., or 4.15 lbs. per rated h.p.

A four-cylinder water-cooled Vee type engine of 94 mm. (3.7 in.) bore, 114 mm. (4.48 in.) stroke, and a total displacement of 192.68 cu. in., was rated 50 h.p. at 1250 r.p.m. The weight was said to be 155 lbs., or 3.1 lbs. per rated h.p.

A six-cylinder vertical water-cooled engine of the same cylinder dimensions, and therefore having a total displacement of 289.02 cu. in., was rated 90 h.p. at 1250 r.p.m. The weight was said to be 320 lbs., or 3.56 lbs. per rated h.p.

Fig. 345. The Neilsen and Winther Engine.

NEILSEN & WINTHER

A six-cylinder vertical water-cooled engine was constructed by Neilsen and Winther of Presundsvej, Copenhagen, Denmark. This engine was quite similar to the German Mercedes in design, but had carburetors and inlet manifolds arranged in the same manner as those on the Benz engines.

NIEUPORT

The Nieuport was a two-cylinder horizontally-opposed air-cooled engine built in France during 1911. The bore was 135 mm. (5.31 in.), the stroke 150 mm. (5.91 in.), and the total displacement 261.76 cu. in. This engine was rated 32/35 h.p. at 110 r.p.m., and reported to weigh 173 lbs., or 5.41 lbs. per rated h.p.

NORTON

A two-cylinder horizontally-opposed air-cooled engine of 4 in. bore, 4.5 in. stroke, and 113.1 cu. in. total displacement, was designed and built by Kenneth Norton of the Norton-Newby Motorcycle Co. of Kansas City, during 1911.

Fig. 346. The Novus Rotary Engine.

NOVUS

The six-cylinder air-cooled engines, formerly built by Horch and Company of Zwickau, Germany, had a 120 mm. (4.72 in.) bore, 130 mm. (5.12 in.) stroke, and 537.54 cu. in. total displacement. These engines developed 70 h.p. at 1200 r. p.m. and were said to weigh 221 lbs., or 3.15 lbs. per rated h.p. Two types were built, one a conventional rotary with fixed crankshaft and rotating cylinders, and the other a double rotary in which both cylinders and crankshaft revolved in opposite directions at half speed and drove two propellers.

These engines were constructed entirely of alloy steel and employed ball bearings throughout. Both inlet and exhaust valves were mechanically operated through push rods by a

cam specially arranged to control the valves in groups of three. The pistons were lubricated by oil led from a ring-shaped oil canal to the surface through tubes in the direction opposite to the rotation of the engine.

OBERURSEL

The Oberursel Motoren Gesellschaft of Frankfurt, Germany, was licensed before the war to build air-cooled rotary engines after the Gnome principle. Construction, however, more closely followed Le Rhone designs.

The cylinders with cooling flanges are machined from solid billets of steel. The connecting rods are of the articulated type, the master rod being supported on the crankshaft by two ball bearings. The inlet valves in the pistons are operated automatically, and the exhaust valves in the cylinders by means of push rods and rockers. The carburetor is attached directly to the fixed hollow crankshaft which also carries the oil tubes that are fed from a plunger pump.

The seven-cylinder model is rated at 80 h.p. The bore is 124 mm. (4.88 in.), the stroke 140 mm. (5.51 in.), and the total displacement 721.49 cu. in.

The nine-cylinder engine with 124 mm. (4.88 in.) bore, 150 mm. (5.91 in.) stroke, and 994.95 cu. in. total displacement, is rated at 100 h.p.

The fourteen-cylinder engine, a double form of the seven-cylinder model, is rated at 160 h.p. The total piston displacement is 1442.98 cu. in.

The eighteen-cylinder model is rated at 200 h.p. This engine is composed of two sets of 100-h.p. engine cylinders and has a total displacement of 1989.9 cu. in.

This company experimented with a water-cooled eight-cylinder Vee type geared engine rated 240 h.p. at 2100/2200 r.p.m. The peak of the power curve was at 2800 r.p.m. This engine was said to weigh 573 lbs., or 2.39 lbs. per rated h.p.

OERLIKON

The Oerlikon Engine was constructed in the Swiss Machine Factory at Oerlikon, near Zürich. The bore was 100 mm. (3.94 in.), the stroke 200 mm. (7.87 in.), and the total dis-

placement 384.32 cu. in. It was rated 50/60 h.p. at 1000/1200 r.p.m. and was said to weigh 176 lbs.

The four horizontally-opposed cylinders, arranged in pairs, were constructed separately from nickel steel and surrounded by corrugated sheet-copper water jackets. Concentric valves were placed co-axially in the cylinder heads and

Fig. 347. Plan View of Oerlikon Engine.

operated by long push rods and rockers from two-stage cams. A series of holes, serving as auxiliary ports, disposed of part of the exhaust near the end of the expansion stroke. The cooling water entered the jackets from underneath and left through connections on top. A magneto supplied two spark plugs located diametrically opposite in each cylinder, and the

carburetors were attached directly to the heads of each pair of cylinders.

The crankshaft was not enclosed in a crankcase. This effected a saving in weight and doubtless improved the cooling of the piston and cylinders on the inside, but on the other hand it afforded no protection from dirt and made the lubrication of the working parts more difficult. The three-throw crankshaft was forged from a round bar of nickel steel. Two opposite connecting rods acted upon the center crankpin which was made wider than the others. The crankshaft and both ends of the connecting rods were fitted with ball bearings. This arrangement was chosen in order to obtain good balance.

OLDFIELD

The Oldfield (Model 15-A) engine was rated 150 h.p. at 1500 r.p.m. The bore was 2.875 in. and the stroke 4.625 in. The ignition was furnished by a special Atwater-Kent unit, and the weight was said to be 225 lbs.

OPEL

The Adam Opel Motor Works of Rüsselsheim, Germany, first built the Type III 180-h.p. Argus design described below. The firm later designed and built an experimental model estimated to develop 200 h.p. This engine had nine-cylinders, arranged in three rows of three, and was fitted with propeller reduction gears. The design was abandoned in favor of the B. M. W. III-a engine.

Type III. This engine was rated 180 h.p. at 1400 r.p.m. and 190 h.p. at 1600 r.p.m. The bore was 145 mm. (5.71 in.), the stroke 160 mm. (6.30 in.), and the total displacement 967.98 cu. in. The compression ratio was 4.75, and the maximum brake mean effective pressure, which occurred at 1250 r. p.m., was 107 lbs. per sq. in. The fuel consumption was stated to be .542 lbs. per h.p-hr., and the oil consumption .018 lbs. per h.p-hr. The total weight was reported to be 756 lbs., or 4.2 lbs. per rated h.p.

The cylinders were made up in pairs from steel forgings, being welded together at the flange, and encased by a common water jacket. They were offset from the crankshaft

Fig. 348. Inlet Side of Opel Engine.

center line 18 mm. An inlet and exhaust valve, each with 66 mm. (2.598 in.) clear diameter and 45 degree seats, were situated in the cylinder head, and operated by means of push rods and rockers from a cam·shaft that was driven from the crankshaft by spur gears. The inlet valve lift was 11.35 mm. (.447 in.), and the exhaust valve lift 11 mm. (.433 in.). The valve timing was as follows: the inlet opened 12 degrees early and closed 80 degrees late; the exhaust opened 66 degrees early and closed 13 degrees late.

The crankshaft was a six-throw type with seven plain bearings. The cross section of the crank cheeks were progressively increased toward the propeller end. The connecting rods had "H" sections and two-bolt caps, the lower ends being

Fig. 349. Transverse Section of Opel 180-h.p. Engine.

offset so as to evenly space the bearings of the crankshaft between the two cylinders located close together. The pistons were made from aluminum and fitted with three rings.

Two German built Zenith carburetors, having 39 mm. chokes, 305 cc. main jets, and 505 cc. compensating jets, supplied the mixture. Lubrication was provided by a multi-plunger pump. The water was circulated by a centrifugal pump of 24 gals. per min. capacity, and dual ignition was supplied by two Bosch Z-H-6 magnetos.

Fig. 351. The Propeller End of Orlo Eight-Cylinder Engine.

ORLO

The Orlo Motor Co. of Rochester, N. Y., built three water-cooled engines during 1916.

B-4. The Model B-4 Orlo engine was a four-cylinder vertical type, rated 50 h.p. at 1300 r.p.m. The bore was 4.5 in., the stroke 6 in., and the total displacement 381.69 cu. in. The cylinders were cast separately and employed overhead valves. Dual ignition was provided, and a Schebler carburetor furnished the mixture. The bare weight of the engine was reported as 220 lbs., or 4.4 lbs. per rated h.p.

B-6. The Orlo Model B-6 engine was rated 75 h.p. at 1300 r.p.m. The cylinders were identical to those of the B-4 type, hence the total displacement was 572.54 cu. in. The weight of the bare engine was said to be 270 lbs., or 3.6 lbs. per rated h.p.

Fig. 352. The Orlo Eight-Cylinder 100-h.p. Engine.

B-8. An eight-cylinder 90 degree Vee type engine, known as Model B-8, was rated 100 h.p. at 1300 r.p.m. This engine employed the same cylinders as the B-4 and B-6 models, the total displacement being 763.37 cu. in. The bare weight was reported to be 480 lbs., or 4.8 lbs. per rated h.p.

OTIS-PIFRE

Ateliers Otis-Pifre, 161-176 Rue de Courcelles, Paris, France, have built an experimental six-cylinder vertical engine. They have also produced a twelve-cylinder 60 degree Vee type water-cooled geared engine, rated 500 h.p. at 2000 r.p.m. The bore was 130 mm. (5.12 in.), the stroke 160 mm. (6.3 in.), and the total displacement 1555.32 cu. in. The cylinders were offset from the crankshaft center line, and the weight was reported to be 1213 lbs., or 2.42 lbs. per rated h.p. The overall dimensions were as follows: length 78.74 in., width 33.46 in., and height 35.43 in.

OTTO

The Gustav Otto Aeromotors, designed by Engineer Geisenhof, were vertical water-cooled types with separately cast and machined cylinders, grouped in a single block by means of flanges, and bolts which passed through the water jackets from the front to the rear. Lubrication was by an eccentric oil pump, and ignition by a Bosch magneto.

The four-cylinder 50-h.p. model had a 110 mm. (4.33 in.) bore, 150 mm. (5.91 in.) stroke, and 348.12 cu. in. total displacement. This engine had "L" head type cylinders with valves operated directly through tappets. The spark plugs were located in plugs directly over the inlet valves. The connecting rods had "H" sections, and the crankshaft was carried in three plain bearings. Each side of the front plain bearing was a radial ball bearing for taking the propeller thrust loads.

The six-cylinder model, employing the same cylinders, had a total displacement of 522.18 cu. in., and was rated at 70 h.p.

Four and six-cylinder vertical engines were built with a 140 mm. (5.51 in.) bore and 150 mm. (5.91 in.) stroke. The four-cylinder model had a total displacement of 563.68 cu. in. and was rated at 80/100 h.p. The six-cylinder engine with a total displacement of 845.52 cu. in. was rated at 100/130 h.p. In these engines the valves were situated vertically in the

Fig. 353. The 80-h.p. Gustav Otto Aeromotor.

cylinder head and operated by means of push rods and rockers.

The Otto Works have also produced an eight-cylinder vertical water-cooled engine rated at 200 h.p.

PACKARD

The Packard Motor Car Company of Detroit, Michigan, designed and constructed two types of airplane engines which Mr. J. G. Vincent, the Packard vice-president of Engineering, offered the U. S. Government shortly after America's entrance into the war. It was decided, however, to design and build standard Government types that were more suited to the requirements of that time than any of the existing American or European models. Mr. Vincent was chosen as one of the designers of the Liberty enigne, and given a commission of Major in the Army. Later he was promoted to Lieutenant Colonel, and placed in charge of the development work at McCook Field, Dayton, Ohio. At the signing of the Armistice Mr. Vincent returned to the Packard Company, and with the Liberty engine experience built three new models of similar design.

905. The first Packard attempt at airplane engine construction was the Model 905. This was a twelve-cylinder

Fig. 354. The Packard 905 Engine.

water-cooled Vee type engine of 4 in. bore, 6 in. stroke, and 904.8 cu. in. total displacement. The 905 engine was rated 225 h.p. at 2100 r.p.m., employed plain type spur reduction gears for the propeller drive, and was reported to weigh 800 lbs., or 3.55 lbs. per rated h.p.

The cylinders were built up from steel forgings in blocks of three and encased in a common pressed-steel water jacket welded in place. The valves were situated in the cylinder head and operated by rockers from an overhead camshaft that was driven through a train of spur gears. There were two spark plugs per cylinder. The six-throw crankshaft was of the three-bearing type, the forked connecting rods had "H" sections, and the aluminum pistons were fitted with three rings. The engine was equipped with a Bijur electric starter and generator.

Fig. 355. End View of Packard 744 Engine.

Model 744. The 744 and 1116 Packard models were the first to be developed after the war. These were eight and twelve-cylinder 60 degree Vee type water-cooled engines, respectively, of 4.75 in. bore and 5.25 in. stroke, with a compression ratio of approximately 5 to 1.

The Model 744 had a total displacement of 744.24 cu. in., was rated 180 h.p. at 1600 r.p.m., and developed approximately 200 h.p. at a maximum speed of 2000 r.p.m. At 1200 r.p.m., 126 lbs. per sq. in. b.m.e.p. was the maximum developed. The dry weight was reported to be 542 lbs., or 3.01 lbs. per rated h.p., and the water content of the engine was approximately 26 lbs.

Fig. 356. The Packard 744 Aircraft Engine.

A Packard Zenith duplex 2 in. carburetor, having 1.75 in. chokes, number 49 main jets, and number 50 compensating jets, was mounted underneath on the lower-half crankcase. The mixture passed through cored passages in the case and was delivered to the inlet manifolds in the Vee by pipes, flanged to the upper half and passing between the cylinders

of either row opposite the center bearing. The fuel consumption was reported to be .484 lbs. per h.p-hr., and the oil consumption .056 lbs. per h.p-hr. Lubrication was of the pressure-feed dry-sump type with a gear pump delivering approximately 48 lbs. normal pressure to the crankshaft bearings.

The separate cylinders were of built-up steel and welded construction, single inlet and exhaust valves being situated in the head, slightly inclined to the vertical axis, and operated through rockers by an overhead camshaft. The clear diameter of each valve was 2 in. and the valve seats were at an angle of 30 degrees. The inlet valve lift was .4375 in. and the exhaust valve lift .375 in. The valve timing was as follows: the inlet opened 10 degrees late and closed 45 degrees late; the exhaust opened 48 degrees early and closed 8 degrees late.

The crankshaft was a four-throw five-bearing type fitted with a double-row ball bearing to carry the propeller thrust load. The forked type connecting rods had "H" sections, and the aluminum pistons were fitted with three top rings. Dual ignition was furnished by a Delco battery system including distributors and generator. The overall dimensions were as follows: length over propeller hub 49.875 in., width 27.125 in., and height 33.5 in.

Fig. 357. The Packard 1116 Engine.

1116. The Packard 1116 model, with a total displacement of 1116.36 cu. in., developed 282 h.p. at 1600 r.p.m. The total dry weight was reported to be 733 lbs., or 2.6 lbs. per h.p., and the water content of the engine was 41 lbs. The fuel consumption was .46 lbs. per h.p-hr., and the oil consumption .035 lbs. per h.p-hr. The overall dimensions were as follows: length over propeller hub 62.25 in., width 27.125 in., and height 33.5 in.

Fig. 358. The Packard 2025 Engine.

2025. The largest of the Packard series, the Model 2025, was used in the Verville (VCP-1) plane which won the Pulitzer race held on Long Island Thanksgiving Day, 1920. This engine employs the same general form of construction as the 744 and 1116 models. The bore is 5.75 in., the stroke 6.5 in., and the total displacement 2025.42 cu. in.

This 2025 engine is rated 540 h.p. at 1800 r.p.m., and has delivered 556 h.p. at this speed and 585 h.p. at a maximum speed of 2000 r.p.m. At 1500 r.p.m. 124 lbs. per sq. in. b.m.e.p. is developed. The fuel consumption is reported to be .503 lbs. per h.p-hr., and the oil consumption .065 lbs. per h.p-hr. The dry weight is said to be 1126 lbs., or 2.08 lbs. per rated h.p.

The cylinders of the 2025 model are fitted with four valves of 2 in. clear diameter and 30 degree seats. The inlet valve lifts .4375 in. and the exhaust valve .375 in. The valve timing is as follows: the inlet opens 10 degrees late and closes 45 degrees late; the exhaust opens 48 degrees early and closes 8 degrees late.

1237. The Packard 1116 engine has been superseded by the Model 1237; the cylinder bore is enlarged .25 in. and the compression ratio increased to 6.5, thus making it an over-dimensioned and over-compressed engine for altitude work. The bore is then 5 in., the stroke 5.25 in., and the total displacement 1236.96 cu. in. The engine develops normally 315 h.p. at 1600 r.p.m. and 374 h.p. at 2000 r.p.m. The total dry weight is reported as 737 lbs., or 2.34 lbs. per normal h.p.

The engine is otherwise practically the same as the 1116 model except that magneto ignition is provided. This is one of the first American built engines to employ the many times proposed scheme of using a high compression ratio to give the desired performance at certain altitudes, and throttling near the ground so that the engine will not detonate or exceed safe loads.

825. Applying the larger cylinders to the former eight-cylinder 744 model increases the total displacement of this engine to 824.64 cu. in.

PALONS & BEUSE

The Palons and Beuse engine was a German built two-cylinder horizontally-opposed air-cooled type. The cylinders were constructed of cast iron and provided with lugs on the head for attachment to the crankcase by means of long bolts. The valves were located in the cylinder head; the exhaust was operated through a push rod and rocker, and the inlet was automatic. A carburetor was attached directly to each cylinder at the combustion chamber.

PANHARD

The Panhard-Levassor Automobile Works of Paris, France, have for several years built water-cooled airplane engines in vertical and Vee forms. Panhard engines were among

the first to employ steel cylinders; some with this type of construction appeared as early as 1903.

The four cylinder vertical Panhard airplane engines, developed during 1908, employed steel cylinder barrels, cast-iron heads, and corrugated sheet-copper water jackets which were clamped by screws at the top and soldered at the lower end. Co-axially in the heads of these separately constructed cylinders were situated concentric type valves of rather novel design that were operated through single push and pull rockers by plus-and-minus cams. Both steel and cast iron have been employed as the material for pistons

Fig. 359. The Panhard Four-Cylinder 35-h.p. Engine.

The four-cylinder vertical water-cooled engine of 110 mm. (4.33 in) bore, 140 mm. (5.51 in.) stroke, and 324.56 cu. in. total displacement, was rated at 35 h.p. This engine was said to have developed 43 h.p. at 1100 r.p.m. continuously for several hours, and to weigh complete 220 lbs., of 5.1 lbs. per actual h.p.

A Panhard four-cylinder vertical engine, rated 48.5 h.p. at 900 r.p.m., was said to weigh 466 lbs., or 9.6 lbs. per rated h.p. The cylinder bore was 125 mm. (4.92 in.), the stroke 150 mm. (5.91 in.), and the total displacement 449.44 cu. in.

A four-cylinder vertical engine of 170 mm. (6.69 in.) bore and stroke, and 949.64 cu. in. total displacement, was rated 90 h.p. at 900 r.p.m. The complete weight was reported to be 523 lbs., or 5.8 lbs. per rated h.p.

The largest Panhard airplane engine of four cylinders had a 185 mm. (7.28 in.) bore, 200 mm. (7.87 in.) stroke, and 1310.36 cu. in. total displacement. This engine was rated 112 h.p. at 900 r.p.m. and stated to weigh complete 836 lbs., or 7.5 lbs. per rated h.p.

In 1912, Panhard and Levassor built an eight-cylinder water-cooled Vee design, which was rated 100 h.p. at 1500 r. p.m. The bore was 110 mm. (4.33 in.), the stroke 140 mm. (5.51 in.), and the total displacement 649.12 cu. in. The dry weight was reported as 440 lbs., or 4.4 lbs. per rated h.p.

Fig. 360. The Panhard Eight-Cylinder Engine.

The cylinders were made from cast iron in blocks of four with the water jackets integral. The side-by-side valves, in the L head cylinder arrangement, were operated directly through tappets from a camshaft in Vee. The pistons were of pressed steel, and the connecting rods had "H" sections. The propeller was mounted on an extension of the camshaft, which was driven by gears at both ends of the engine with the object of reducing crankshaft torsional vibration.

V-12-J. The Panhard V-12-J was a twelve-cylinder 60 degree Vee type water-cooled engine of 115 mm. (4.53 in.) bore, 170 mm. (6.69 in.) stroke, and 1293.84 cu. in. total displacement. This engine was built with either direct or reduction gear driven propeller. The direct drive engine was

rated 340 h.p. at 1700 r.p.m, and reported to weigh 992 lbs., or 2.92 lbs. per rated h.p. It consumed .452 lbs. of fuel per h.p-hr. The geared type, rated 350 h.p. at 1800 r.p.m., was said to weigh 1080 lbs., or 3.09 lbs., per rated h.p.

Fig. 361. Transverse Section of Panhard Type V-12-J Engine.

The cylinders were made separately from cast iron; core plates for the water jackets being provided on the adjacent sides. Valves of 56 mm. (2.2 in.) clear diameter were inclined in the cylinder head. A seven-bearing camshaft, which was enclosed in a long aluminum housing supported upon the tops of the cylinders, operated the valves through rockers. The cylinders were mounted desaxe 20 mm. upon an aluminum crankcase. The timing of the valves was as follows: the in-

Fig. 362. Section Through Cylinders of Panhard V-12-J Engine.

let opened 5 degrees early and closed 35 degrees late; the exhaust opened 50 degrees early and closed 15 degrees late.

The pistons were aluminum castings with six internal ribs and four top rings. The connecting rods were of the forked type and had "H" sections. A six-throw seven-bearing crankshaft had a thin circular disc serving as a crank-cheek between each crank-pin and large diameter main journal.

Panhard carburetors were situated in the Vee, and two centrifugal pumps, mounted at right angles to the crankshaft and driven by spiral gears, maintained water circulation. These engines were sometimes equipped with air starters, in which case the distributing disc was mounted at the propeller end of the camshaft housing. Lubrication was of the force-feed type, the supply of oil being carried in a large reservoir attached to the lower half crankcase and separated from it by large s

Fig. 363. Panhard Twelve-Cylinder Engine.

An experimental design of twelve cylinders in 60 degree Vee form was rated 500 h.p. at 1500 r.p.m. The bore was 145 mm. (5.71 in.), the stroke 170 mm. (6.69 in.), and the total displacement 2055.72 cu. in. The compression ratio was 5.3, and the propeller was direct driven. The weight was estimated at 920 lbs., or 1.84 lbs. per rated h.p.

A large Panhard twelve-cylinder Vee engine, similar to the V-12-J design, had a 165 mm. (6.5 in.) bore, 180 mm. (7.09 in.) stroke, and a total displacement of 2823.24 cu. in. This engine was rated at 500 h.p.

The largest airplane engine ever constructed by Panhard and Levassor was the sixteen-cylinder double-Vee type exhibited at the Paris Aero Show in January, 1920. This engine had four rows of four cylinders each, all located above the horizontal centerline. An angle of 45 degrees separating each adjacent row made the total included angle between the outer rows 135 degrees.

The bore was 145 mm. (5.71 in.), the stroke 170 mm. (6.69 in.), and the total displacement 2740.96 cu. in. This engine was rated 650 h.p. at 1600 r.p.m., 700 h.p. at 1700 r.p.m., and was reported to have developed 720 h.p. at 1600 r.p.m. The compression ratio was 5 to 1, and the propeller was direct driven. The fuel consumption was said to be .54 lbs. per h.p-hr.

Fig. 364. The Panhard Sixteen-Cylinder Engine.

The separate steel cylinders had welded-on sheet-steel jackets, and four vertical valves in each head operated by two push rods from one of the two camshafts that were situated in the outer Vees of the crankcase. A roller in one end of the rocker arm made contact with a bridge between each pair of valves.

The crankshaft was a conventional four-throw five-bearing type with 180 degrees between throws. The connecting

rods were of the articulated type, and the aluminum pistons were fitted with five rings.

The mixture was furnished by four Panhard and Levassor carburetors, and pressure lubrication by three gear pumps. There were two magnetos, with double distributors mounted crosswise at each end of the engine, which fired four spark plugs per cylinder. The approximate overall dimensions of the engine were as follows: length 51 in., width 49 in., and height 43 in.

PEUGEOT

The first airplane engine, built by the Peugeot Company in France, followed closely the design of the successful racing car engines which they began constructing in 1910. This engine had eight cylinders in 90 degree Vee arrangement of 100 mm. (3.94 in.) bore, 180 mm. (7.09 in.) stroke, and 691.52 cu. in. total displacement. The rated output was 200 h.p. at 2000 r.p.m.; however, 230 h.p. has been regularly developed at this speed. The total weight was said to be 882 lbs., or 4.41 lbs. per rated h.p.

Fig. 365. Transverse Section of 200-h.p. Peugeot Engine.

Plain spur reduction gears, with the propeller shaft extending well out in front and mounted on ball bearings, gave the propeller a speed of .5 that of the crankshaft. A shaft, extending directly back through the Vee, drove the camshaft spur gear train and the accessory units. The crankcase was of the barrel type, the four-throw crankshaft being supported in three large double-row ball bearings. The crankshaft was made from two sections and joined at the center bearing by a taper, key, and nut.

Fig. 366. Gear Train of Peugeot 200-h.p. Engine.

The cylinders were cast from iron in blocks of four with water jackets integral, the large cored opening at the ends of the block being closed by an aluminum plate held in place by screws. The cylinder blocks were offset from the crankshaft centerline. In each cylinder head were four inclined valves of 44 mm. (1.73 in.) clear diameter, guided in bronze bushings. Four super-imposed camshafts, each enclosed in an aluminum housing, operated the valves through tappets. The valve timing was as follows: the inlet opened 11 degrees and 44 minutes late and closed 46 degrees and 7 minutes late; the exhaust

opened 52 degrees and 30 minutes early and closed 7 degrees and 44 minutes late.

The pistons were machined from steel forgings and fitted with two rings. The connecting rods were of the forked type and had "H" sections. Claudel carburetors attached to outside inlet manifolds, that were jacketed and heated by means of the exhaust gas, supplied four cylinders each. The cooling water was circulated by two centrifugal pumps, and dual ignition was provided by two eight-cylinder S. E. V. magnetos. One spark plug was situated in the center of the cylinder head and the other in an inverted position just below the inlet valve on the outside. The lubricating system was of the pressure-feed dry-sump type.

Type 16 AJ. One of the most recent Peugot types, built on the A. Jouffret system, has sixteen cylinders formed by the virtual coupling of two eight-cylinder engines of the 90 degree Vee type. These are joined at the center and drive through propeller reduction gears having a ratio of .75.

Fig. 367. End View of Peugeot Type 16 AJ.

The bore is 120 mm. (4.72 in.), the stroke 160 mm. (6.3 in.), and the total displacement 1763.68 cu in. The engine is said to deliver 440 h.p. at 1800 r.p.m. and weigh 1049 lbs., or 2.37 lbs. per h.p. The compression ratio is 5 to 1. The approximate overall dimensions are as follows: length over propeller hub 77 in., width 38.5 in., and height 31.5 in.

Steel cylinders are screwed into a cast-iron cylinder head and surrounded by an aluminum water jacket. There are four vertical valves of 37 mm. (1.46 in.) clear diameter and 45 degree seats in each cylinder head, a single overhead enclosed camshaft controlling the valves in each group of four cylinders through double rocker arms.

The two four-throw crankshafts, with crank-pins 180 degrees apart, are each supported at the outer ends by double-

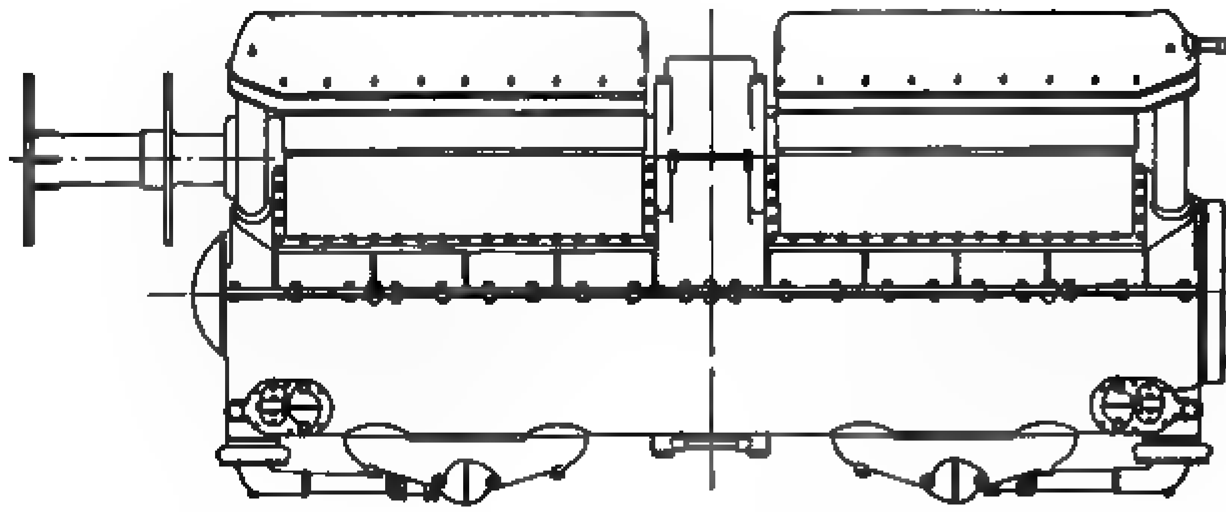


Fig. 368. Side View of Peugeot Type 16 AJ.

row ball bearings and at the intermediate positions by three plain bearings; and at the center are joined by tapers and keys to the driving gear, which is supported in the crankcase by two double-row ball bearings. The long propeller shaft is supported in amply proportioned plain bearings.

The aluminum pistons have five parallel and vertical internal ribs and are fitted with two sets of double rings and a single oil scraper ring. The connecting rods are of the forked type and have tubular sections. A large centrifugal water pump is mounted at the forward end of crankcase and driven from the crankshaft.

Two duplex carburetors, situated in the Vee, feed into water-jacketed four-cylinder manifolds, and dual ignition is supplied by four eight-cylinder magnetos. Double gear oil pumps, disposed at each end of the engine and driven by an

Fig. 369. Plan View of Peugeot Type 16 AJ.

endless screw, are adjusted to maintain a constant pressure of 10 lbs. A compressed air starter is adapted to each group of eight cylinders with the distributor gears fastened to the ends of the camshafts. A pulley for generator drive is driven from the rear end of the crankshaft and arranged with disengaging mechanism and hand clutch.

Fig. 370. Longitudinal Section of Peugeot Type 16 AJ.

Type L-41. The Peugeot Type L-41 is a direct drive twelve-cylinder 60 degree Vee type water-cooled engine, rated 600 h.p. at 1600 r.p.m. The bore is 160 mm. (6.3 in.), the stroke 170 mm. (6.69 in.), and the total displacement 2502.48 cu. in. The compression ratio is 4.7, and the weight is reported to be 1270 lbs., or 2.11 lbs. per rated h.p. The approximate overall dimensions are as follows: length over propeller hub 80 in., width 42 in., and height 43 in.

The cylinders are enamelled aluminum, in blocks of three, with closed end steel liners screwed into place. Four vertical valves in each cylinder head, of 52 mm. (2.05 in.) clear diameter and 45 degree seats, are operated by rockers from an enclosed camshaft extending over six cylinders and driven at center by a vertical shaft and bevel gears.

The crankshaft is a six-throw seven-bearing type with plain bearings except at the ends where rollers are employed. The connecting rods are of the forked type and have tubular sections. The aluminum pistons have six parallel ribs underneath the head and are fitted with three double ring sets and one single oil scraper ring.

Fig. 371. Longitudinal Section of Peugeot Type L-41.

Each group of six cylinders is fed from a duplex carburetor situated on the outside and receiving its intake air through a passage in the lower half crankcase. The inlet pipes cross to the Vee through the camshaft covers. The

Fig. 372. End View of the Peugeot Type L-41.

cooling water is circulated by two centrifugal pumps disposed at the rear of the engine. Just above, in two separate planes, are symetrically mounted four S. E. V. six-cylinder magnetos that supply dual ignition. Two double gear oil pumps, placed on the lower part of the crankcase, are driven from a vertical shaft and bevel gears immediately below the center main bearing.

Fig. 373. Section of Peugeot Type 16 X.

Type 16 X. The Peugeot Type 16 X, as the name implies, is a sixteen-cylinder X type engine, composed of four rows of four cylinders 90 degrees apart. This engine is water-cooled, uses a direct driven propeller, and has a compression ratio of 5.3. The bore is 130 mm. (5.12 in.), the stroke 170 mm. (6.69 in.), and the total displacement 2215.36 cu. in. The engine is said to develop 500 h.p. at 1400 r.p.m. and weigh complete 994 lbs., or 1.98 lbs. per rated h.p. The approximate overall dimensions are as follows: length over propeller hub 63 in., width 37.5 in., and height 37.5 in.

The cylinders are formed in blocks of four, from steel barrels screwed and welded into a cast-iron cylinder head, and encased in an aluminum water jacket which is bolted to the

crankcase. Four vertical valves in the cylinder head, of 40 mm. (1.57 in.) clear diameter and 45 degree seats, are operated by means of double rocker arms provided with an eccentric roller adjustment. The overhead enclosed camshaft is driven at the end by vertical shaft and bevel gears.

The two sections of the four-throw crankshaft are connected at the center bearing by a pinned cone blocked by a bolt. The crankshaft is supported by a large central ball bearing and two long plain end bearings. The connecting rods are of the articulated type and all have tubular sections. The aluminum pistons are fitted with two double rings and two single rings, the lower single ring serving as an oil scraper.

Fig. 374. End View of Peugeot Type 16 X.

One centrifugal pump, situated underneath at the rear of the engine, circulates the cooling water to all four cylinder blocks. Forced lubrication is maintained by gear pumps, and dual ignition is provided by four magnetos disposed at the end in the plane of the cylinders. Each four cylinder group has a special carburetor that is attached to the end of the inlet manifold and warmed by the circulation of water. A compressed air starter is provided for the two upper rows of cylinders.

Fig. 375. The Pierce Three-Cylinder Radial Engine.

PIERCE

A three-cylinder air-cooled radial engine, built by the Samuel S. Pierce Airplane Co. of Southhampton, Long Island, and known as the Pierce Model B, was rated at 35 h.p. This engine had a 4 in. bore, 6 in. stroke, and 226.19 cu. in. total displacement.

The cylinders had detachable heads and barrels fitted with liners. The valves in the cylinder head were operated by push

rods from individual cams driven by spiral gears. The inlet and exhaust valve each had an effective diameter of 1.6875 in. and a lift of .375 in.

The single-throw crankshaft was mounted in plain bearings, and the connecting rods were of the slipper type with tubular sections. The wrist pin was clamped in the upper end of the rod, bearing entirely in the cast-iron pistons that were fitted with two top rings. Force-feed lubrication was provided by an eccentric vane pump, and magnetos furnished the ignition. The engine measured 41 in. in outside diameter and 24 in. in overall length.

PIPE

The Pipe eight-cylinder 90 degree Vee type air-cooled engine, which was designed and built in Belgium during 1910, was quite similar to the French Renault air-cooled types. The bore and stroke were 100 mm. (3.94 in.), and the total displacement 384.32 cu. in. The Pipe engine was normally rated 50 h.p. at 1200 r.p.m., and 70 h.p. at a maximum speed of 1950 r.p.m. The weight was reported to be 289 lbs., or 5.78 lbs. per normal h.p.

Fig. 376. Longitudinal Section of Pipe Engine.

Fig. 377. Transverse Section of Pipe Engine.

Cast-iron cylinders, with integrally cast cooling flanges, had concentric type valves situated in the cylinder head. Opposite cylinders in the Vee were staggered in respect to one another sufficiently to permit the use of side-by-side connecting rods. The crankshaft was mounted in three large ball bearings, the same type of mounting being also employed for the camshaft in the Vee. Forced draft circulation was maintained through the aluminum jackets by two blowers.

POTEZ

A four-cylinder air-cooled vertical type engine, designed and built for the Henri Potez Type VII airplane, is mounted in an unusual manner. The crankshaft stands vertically and the cylinder heads project toward the front where the propeller, which is driven at half engine speed through bevel gears at the upper end, blows a blast directly upon them. Since the air attacks the point of highest temperature, the arrangement promises to give effective cooling.

The Potez engine is rated 50 h.p. at 2200 r.p.m. The bore is 100 mm. (3.94 in.), the stroke 120 mm. (4.72 in.), and the total displacement 230.2 cu. in. The fuel consumption is reported to be .529 lbs. per h.p-hr. Cylinders of the "T" head type are constructed separately of steel and fitted with aluminum fins. An oil tank is formed at the timing end of the engine just below the propeller.

Fig. 378. The Potez Upright-Vertical Engine.

PRIMI-BERTHAND

The French built Primi-Berthand engine was a four-cylinder vertical water-cooled type, which operated on the two stroke cycle. The cylinders were fitted with deeply corrugated sheet-copper water jackets.

Fig. 379. The Primi-Berthand Two-Cycle Engine.

R. A. F.

Several types of airplane engines have been designed and developed at the Royal Aircraft Factory, a government experimental station located at Farnboro, England.

R. A. F.-I. Development of the R. A. F.-I engine was undertaken in 1913. This was an air-cooled eight-cylinder 90 degree Vee type, rated at 90 h.p. The bore was 100 mm. (3.94 in.), the stroke 140 mm. (5.51 in.), and the total displacement 537.44 cu. in.

R. A. F.-IA. The design was improved in 1914 and thereafter referred to as the IA model. This engine developed 105 h.p. at 1800 r.p.m, and weighed 440 lbs., or 4.19 lbs. per h.p. The compression ratio was 4.2. These engines were to be used as tractors only on account of the cooling arrangement. The propeller speed was reduced by plain type reduction gears which, together with the cowling employed for directing the air against the cylinders, gave the engine the appearance of the well-known Renault design of which it was a development.

The cast-iron cylinders had integral horizontal cooling fins around the barrel and longitudinal fins across the head. The cylinders were of the "L" head type with the exhaust valve located directly above the inlet. The camshaft in the Vee operated the inlet valves directly through tappets, and the exhaust valves by means of push rods and rockers. The exhaust valves seated directly in the cylinder head, and the inlet valves in cages which were detachable to permit of the removal of the exhaust valve. The inlet valve was 45 mm. (1.77 in.) diameter and its lift 9 mm. (.354 in.). The exhaust valve diameter was 40 mm. (1.57 in.) and its lift 7.5 mm. (.295 in.). The valve timing was as follows: the inlet opened 10 degrees late and closed 40 degrees late; the exhaust opened 52 degrees early and closed 8 degrees late.

Plain type connecting rods with "H" sections and two-bolt caps were placed side by side upon the crankpins by virtue of the staggered cylinder mounting. The pistons were originally made from cast iron and later from aluminum. The crankshaft was carried in four roller bearings and one ball bearing, while the propeller shaft was supported by two ball bearings. A light steel flywheel also served as an oil circu-

lating pump, the system of lubrication being gravity and splash.

The fuel consumption was reported to be .63 lbs. per h.p-hr., and the oil consumption .074 lbs. per h.p-hr. A Claudel-Hobson carburetor with a single float and two mixing chambers was mounted below at the rear end of the engine. The ignition was supplied by two magnetos.

Fig. 380. End View of R. A. F.-IA Engine.

R. A. F.-IB. The major change on the model produced in 1915 was the increase of cylinder bore. This engine had a 105 mm. (4.13 in.) bore, 140 mm. (5.51 in.) stroke, and a total displacement of 590.48 cu. in. A 4.2 compression ratio was employed, and the engine developed 115 h.p. at 1800 r.p.m.

R. A. F.-IC. In 1915 this engine was reproduced with aluminum cylinders having shrunk in liners and side valves. Both 100 mm. and 105 mm. bores were tried with the same stroke of 140 mm., and the compression ratio was increased to 4.5.

R. A. F.-ID. The model ID was in reality an R. A. F.-IA engine with overhead valve aluminum cylinders, similar to those used on the R. A. F.-4D design, and retaining the IA

Fig. 381. Propeller End of R. A. F.-1B Engine.

system of lubrication. This engine was said to develop 150 h.p. at 2000 r.p.m. and weigh 418 lbs., or 2.78 lbs. per h.p. The compression ratio was 4.7.

R. A. F.-1E. The R. A. F.-1E model was a Model 1D using R. A. F.-4E cylinders.

R. A. F.-3A. A water-cooled engine, known as the R. A. F.-3A, was developed from a R. A. F.-3, of similar bore and stroke and general construction, which had very little running. It had twelve cylinders in 60 degree Vee form, and was rated at 200 h.p. The bore was 4.5 in., the stroke 5.5 in., and the total displacement 1049.64 cu. in. When employing the original compression ratio of 4.75, the engine was said to develop 242 h.p. at 1800 r.p.m, and later, with compression increased to 5.5, was said to develop 266 h.p.

The individual cylinders were machined from steel drop forgings with head and valve ports integral with the barrel, and the corrugated sheet-steel water jackets were welded in place. The tulip shaped valves were inclined in the head and

operated by a rocker and single push and pull rod from a camshaft mounted on roller bearings in the Vee. The valve timing was as follows: the inlet opened 24 degrees late and closed 50 degrees late; the exhaust opened 57 degrees early and closed 2 degrees late.

The six-throw crankshaft was supported in eight roller bearings by individual aluminum caps with steel keeps. The crankshaft drove the propeller shaft at half speed through plain type reduction gears. The propeller shaft was carried by two roller bearings and splined to the camshaft at the inner end. The connecting rods were of the articulated type

Fig. 382. The R. A. F.-3A Engine.

with "H" sections, and the aluminum pistons were ribbed and had a cast-in steel piston pin bushing. Three rings were fitted above the piston pin and one below to serve as a scraper.

The inlet manifolds were cast integral with the upper half crankcase and were each supplied by a duplex Claudel carburetor. The gas was fed to the cylinders on the outside through individual steel pipes. Lubrication was by pressure and splash, one set of gears delivering from 35 to 40 lbs. pressure to the bearings and two sets scavenging the sump. The fuel consumption was reported to be .54 lbs. per h.p-hr., and the oil consumption .023 lbs. per h.p-hr. The cooling

water was circulated by two centrifugal pumps, one for each bank of cylinders, and the ignition was by two six-cylinder magnetos mounted crosswise at the propeller end.

R. A. F.-4. An engine with twelve of the model I-A cylinders in 60 degree form was said to develop 140 h.p. at 1800 r.p.m. The total displacement was 806.16 cu. in., and the weight was reported to be 637 lbs., or 4.55 lbs. per h.p. The flywheel oil pump as well as many of the other important

Fig. 383. The R. A. F.-4D Engine.

model 1-A features were closely followed. The valve timing was as follows: the inlet opened 12.5 degrees late and closed 43.5 degrees late; the exhaust opened 61 degrees early and closed 17 degrees late.

R. A. F.-4A. The model produced in 1915, known as the R. A. F.-4A, had a few modifications such as the omission of the flywheel and the substitution of two gear oil pumps. An experimental design was also constructed with Berriman-Daimler designed cylinders having aluminum heads, steel

liners, and copper gills. The latter was said to develop 170 h.p. at 1800 r.p.m

R. A. F.-4D. The design produced in 1916 had aluminum cylinders with liners shrunk in under steam. The cylinders were held down by two studs each. Valves of the tulip type were located overhead, the diameter of the inlet being 43 mm. (1.69 in.) and the exhaust 40 mm. (1.57 in.). The aluminum pistons were fitted with two rings. The compression ratio was raised to 4.7, and the output at 2000 r.p.m was said to be 220 h.p. The weight complete with cowling was reported as 695 lbs., or 3.19 lbs. per h.p.

R. A. F.-4E. A later design with improved cylinders which were held down by four studs and fitted with larger valves,was said to develop 240 h.p. at 2000 r.p.m.

R. A. F.-5. The R . A. F.-5 engine, produced in 1915, was a model 4-A arranged as a pusher. The power output was the same less about 10 h.p. which was required to drive the air circulating fan. The arrangement was very similar to the eight and twelve-cylinder air-cooled Renault designs. The R. A. F.-5 engines were fitted in FE-2B and 2C pusher type machines.

R. A. F.-7. Over 300 h.p. has been developed by the R. A. F.-7 engine, which was a high compression 3-A model fitted with high lift cams and outside exhaust.

R. A. E.-21. An improved A.B.C. "Dragonfly" fitted with new cylinders designed at Farnboro developed about 350 h.p.

R. A. E.-22. The A.B.C. "Wasp" with new cylinder design develops from 180 to 190 h.p.

RAPP

The Rapp Motor Works of Munich, Germany, began building airplane engines just before the war. Water-cooled six-cylinder vertical and eight-cylinder Vee types were constructed. The smaller six-cylinder engine was rated at 125 h.p. and said to weigh 474 lbs.

A six-cylinder vertical engine, rated 150 h.p. at 1350 r.p.m., had a 140 mm. (5.51 in.) bore, 160 mm. (6.3 in.) stroke, and a total displacement of 901.32 cu. in. This engine was reported to weigh 573 lbs., and consume from .485 to .507 lbs. of fuel and .044 lbs. of oil per h.p-hr.

Fig. 384. The Rapp 150-h.p. Engine.

The cylinders were constructed in pairs, forged-steel barrels being screwed into cast-steel heads. A detachable overhead camshaft was driven by a vertical shaft between cylinders four and five, and the valves were so arranged that they could be disassembled without having to remove a cylinder.

A gear pump circulated the oil and an eccentric pump introduced fresh oil into the system. The camshaft employed felt ring lubrication; the cams were greased and the springs and rollers oiled. The magnetos were arranged crosswise between the cylinders and driven from the vertical drive shaft.

Fig. 385. The Rapp Eight-Cylinder Vee Type Engine.

The eight-cylinder Vee type, of the same bore and stroke and consequently with 1201.76 cu. in. total displacement, was rated 200 h.p. at 1350 r.p.m. This engine was reported to weigh 661 lbs., or 3.3 lbs. per rated h.p. The overhead camshafts were driven by vertical shafts between cylinders three and four on each bank. The general arrangement was quite similar to the six-cylinder model.

RAUSENBERGER

The Rausenberger airplane engines were built by the Dayton Aero Motors Company of Dayton, Ohio. Mr. Rausenberger, the designer, later joined the Steel Products Engineering Company of Springfield, Ohio, where the Rausie E-6, his latest design is now being built.

Model A. The first Rausenberger design, built during 1910, was an eight-cylinder Vee type water-cooled engine, rated 45 h.p. at 1350 r.p.m. The bore was 3.5 in., the stroke

Fig. 386. Rausenberger 75-h.p. Engine.

3.75 in., and the total displacement 288.64 cu. in. The engine weighed complete 275 lbs., or 6.1 lbs. per rated h.p. Lubrication was by gravity feed and splash. A Schebler Model L (1.25 in.) carburetor furnished the mixture and a Bosch DR-8 magneto the ignition.

Model B. A larger eight-cylinder model, produced during 1911 and 1912, was rated 75 h.p. at 1350 r.p.m. The bore was 4.125 in., the stroke 4.75 in., and the total displacement 507.84 cu. in. The weight complete was said to be 287 lbs., or 3.82 lbs. per rated h.p.

The cylinders were constructed separately from cast iron and fitted with copper water jackets. The valves were seated vertically in the cylinder head and operated by means of push rods and rockers. The valve timing was as follows: the inlet opened 10 degrees late and closed 25 degrees late; the exhaust opened 45 degrees early and closed 7 degrees late. Lubrication was by pressure from a plunger pump. A Schebler Model L (1.75 in.) carburetor situated in the Vee supplied all cylinders, and ignition was by a Bosch DR-8 magneto.

Model C. A twelve-cylinder 60 degree Vee type water-cooled engine, known as the Rausenberger C-12, was produced during 1914 and 1915. This engine was rated 150 h.p. at 1320 r.p.m., the bore being 4.125 in., the stroke 6 in., and the total displacement 962.21 cu. in. The extreme overall length was 70 in., and the width 24 in. The weight was said to be 590 lbs., or 3.93 lbs. per rated h.p.

The cylinders were very similar to those of the 75-h.p. model. They were made from cast iron and fitted with spun-copper water jackets, and in the cylinder heads were vertically situated valves, whose ports were not jacketed. The valves were 2 in. in diameter and they were lifted .3125 in. by means of push rods and rockers from a camshaft situated in the Vee. The valve timing was the same as in the 75-h.p. type.

The crankshaft was a six-throw type mounted in seven plain bearings. The connecting rods had "H" sections and were arranged side by side upon the crank pins. The pistons were cast from grey iron and fitted with three double rings. Pressure lubrication was provided by a plunger pump, the reservoir in the lower half aluminum crankcase having suffi-

Fig. 387. The Rausenberger Model C-12.

cient capacity for five hours running. The cooling water was circulated by a centrifugal pump driven directly from the end of the crankshaft. Both Splitdorf twelve-cylinder and Bosch DR-6 magnetos have been used, the former for dual ignition and the latter with a single set of plugs.

The C-12 engine, as it was produced in 1916, had new cylinders and a new induction system. The copper water jackets on the redesigned cylinders covered the entire cylinder head including the inlet and exhaust ports. Two duplex Zenith carburetors, situated in the Vee, supplied the cylinders in sets of three. The fuel consumption was said to be .58 lbs. per h.p-hr.

Fig. 388. The Rausenberger C-12 Type of 1916.

Model D. The Rausenberger Model D was designed in 1917. This was a twelve-cylinder Vee type of 5 in. bore, 6.5 in. stroke, and 1531.53 cu. in. total displacement. The compression ratio was 4.76 to 1. The engine was rated 250 h.p. at 1300 r.p.m. and 325 h.p. at 1600 r.p.m. The dry weight was said to be 825 lbs., and the fuel and oil consumption .52 and .03 lbs. per h.p-hr., respectively.

The cylinders were machined from steel forgings and encased in sheet-steel water jackets welded in place. The valves were inclined in the cylinder head and operated from an overhead camshaft through rocker arms. The overhead camshaft was mounted in seven bearings and driven by a train of spur gears.

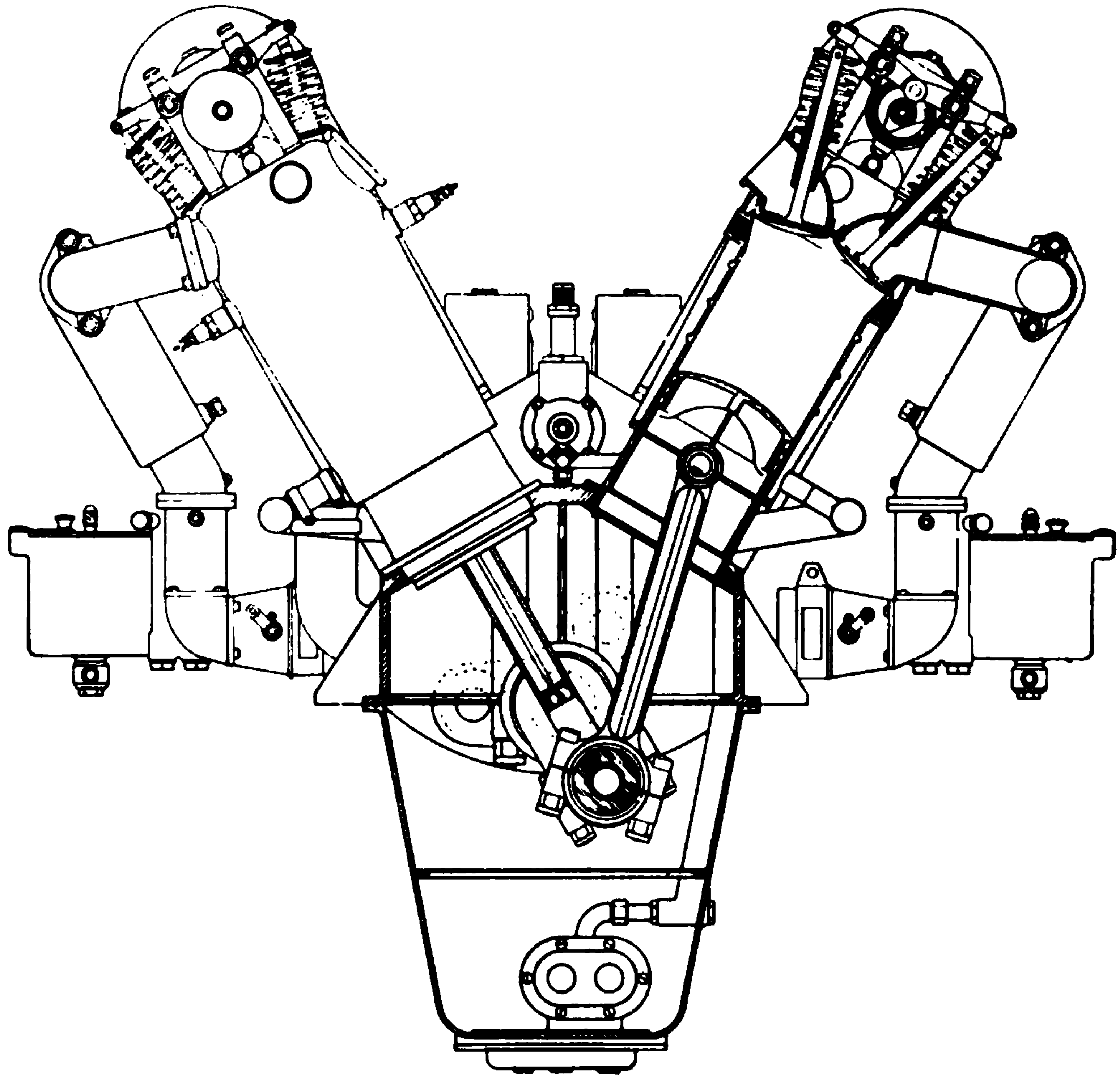


Fig. 389. Section of the Rausenberger Model D.

The six-throw crankshaft was mounted in seven bearings with an extra bearing in the crankcase extension at the propeller end. The connecting rods were of the forked type, and

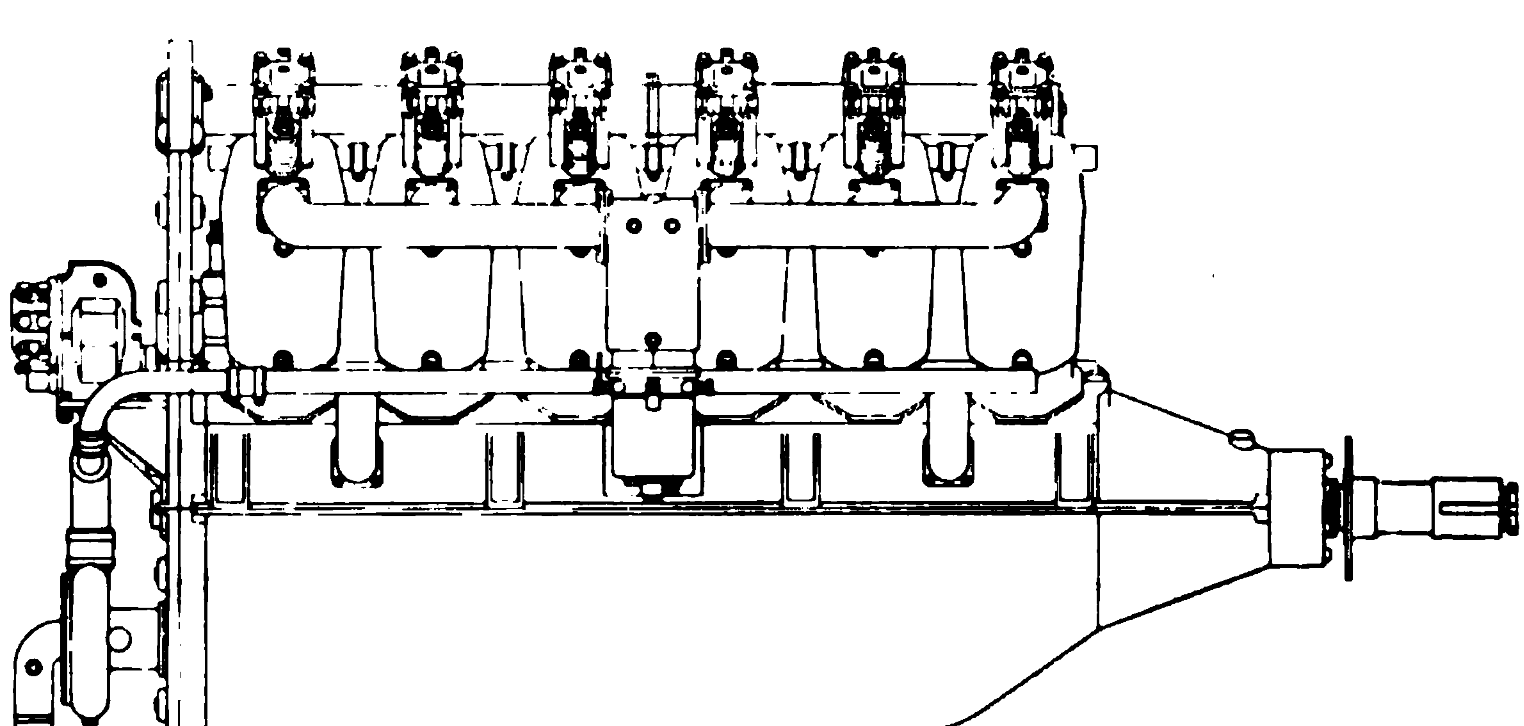


Fig. 390. Side View of the Rausenberger Model D.

the pistons were made from aluminum. Pressure lubrication was maintained by a gear pump, and two duplex Zenith carburetors mounted on the outside furnished the mixture.

Rausie E-6. The Rausie E-6 is a six-cylinder vertical water-cooled engine of 5 in. bore, 6 in. stroke, and 706.86 cu. in. total displacement. It is rated 175 h.p. at 1650 r.p.m., and is said to weigh 510 lbs., or 2.91 lbs. per rated h.p. The compression ratio is 5.5 to 1. The approximate overall dimensions are as follows: length inside propeller hub 51 in., width 21.75 in., and height 47 in.

Fig. 391. Transverse Section of Rausie E-6.

Fig. 392. Longitudinal Section of Rausie E-6.

The cylinders are separately formed from a steel barrel with a screwed on and welded steel combustion chamber that is enclosed by an aluminum water jacket screwed tightly to the head against a copper asbestos gasket and packed at the lower end by a rubber ring. The valves stand vertically in the cylinder head along the center line, and are operated directly from the cams by plungers that are guided in the camshaft housing. The clear diameter of each valve is 2.5 in. and the lift .5 in. The valve timing is as follows: the inlet opens 10 degrees late and closes 40 degrees late; the exhaust opens 48 degrees early and closes 15 degrees late.

The crankshaft is a six-throw seven-bearing type, and the connecting rods have "H" sections. The pistons are made from alumnium and fitted with three top rings and a lower oil scraper ring. Gear pumps are employed to force oil to the bearings and scavenge the sump, and the cooling water is circulated by a centrifugal pump. Two Miller carburetors each supply three cylinders, and two Dixie "600" magnetos furnish dual ignition.

Fig. 393. Inlet Side of Rausie E-6.

RENAULT

Automobiles have been manufactured by Louis Renault at Billancourt, France, since 1898. In 1907, this firm began building airplane engines and the many conventional types which have since been constructed are fairly representative of airplane engine development in France.

One of the first Renault designs was a four-cylinder vertical water-cooled engine rated 38.5 h.p. at 1100 r.p.m. The bore was 110 mm. (4.33 in.), the stroke 160 mm. (6.3 in.), and the total displacement 371.08 cu. in. This engine was said to weigh 286 lbs., or 7.4 lbs. per rated h.p.

Another four-cylinder vertical water-cooled engine, rated 42.5 h.p. at 13C0 r.p.m., had a 116 mm. (4.57 in.) bore, 150 mm. (5.91 in.) stroke, and a total displacement of 387.76 cu. in. The weight was reported to be 880 lbs., or 20.7 lbs. per rated h.p. This engine was designed for use in dirigibles.

Among the earlier Renault models was a water-cooled eight-cylinder Vee type engine having a bore and stroke of 100 mm. (3.94 in.) and 120 mm. (4.72 in.), and a total displacement of 460.4 cu. in. This engine was said to develop 58.5 h.p. at 1200 r.p.m. and weigh 574 lbs., or 9.8 lbs. per h.p.

The smallest Renault air-cooled engine was a four-cylinder Vee type rated at 25/30 h.p. The bore was 90 mm. (3.54 in.), the stroke 120 mm. (4.72 in.), and the total displacement 185.84 cu. in. The weight was said to be 242 lbs.

An eight-cylinder air-cooled Vee type of the same weight was said to develop 35 h.p. The bore was 70 mm. (2.76 in.), the stroke 120 mm. (4.72 in.), and the total displacement 225.92 cu. in. A similar model of 5 mm. larger bore was reported to develop 40 h.p.

An eight-cylinder air-cooled Vee type engine, designed for use in dirigibles, was rated 50.5 h.p. at 1500 r.p.m. The bore was 90 mm. (3.54 in.), the stroke 140 mm. (5.51 in.), and the total displacement 433.84 cu. in. The weight was said to be 550 lbs., or 10.9 lbs. per rated h.p.

One of the most popular of the Renault air-cooled types was the eight-cylinder 50-h.p. model. This engine won a number of victories including the Michelin Cup in 1910 when Mr. Tabuteau made a non-stop flight of nearly eight hours covering a total of 370 miles, and the Michelin Grand Prize of

the same year by Mr. Renaux who covered 225 miles in 4 hours and 54 minutes.

The bore was 90 mm. (3.54 in.), the stroke 120 mm. (4.72 in.), and the total displacement 371.68 cu. in. The normal speed of the engine was 1800 r.p.m. The propeller was driven from the camshaft and consequently operated at half engine speed. The weight was said to be 373 lbs., or 7.46 lbs. per rated h.p., and the overall dimensions were as follows: length 48.5 in., width 26.5 in., and height 25.5 in.

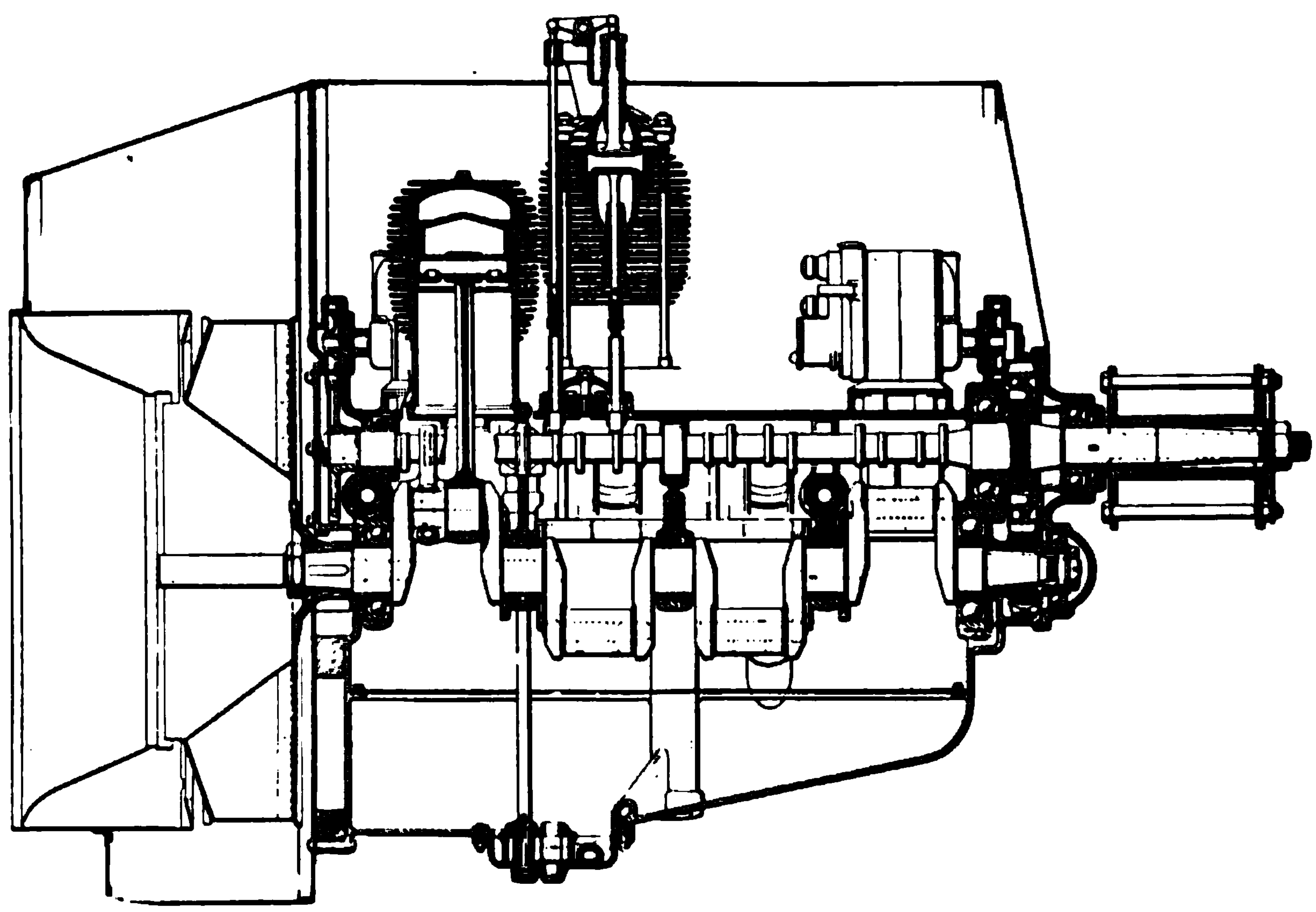


Fig. 394. Longitudinal Section of 70 and 75-h.p. Renault Engines.

The same form of construction was carried at length in several of the larger air-cooled models. The cylinders and heads were made separately from cast iron with cooling fins cast integral upon each. The cylinder head joint was made tight by a copper-asbestos washer, and a clamp pressing against the cylinder head secured the cylinders to the crankcase by the four long studs. On the engines used as tractors, a cowl was fitted to deflect the propeller draught against the cylinders; and for the pusher types, a fan was mounted upon the crankshaft opposite the propeller end and forced air through a casing which partially surrounded the cylinders.

The valves were vertically opposed in a pocket at the side of the combustion chamber. The inlet valve, which was underneath and directly operated by a tappet from the camshaft in the Vee, seated in a cage that also formed the elbow for the inlet pipe. The exhaust valve on top was operated by a push rod and rocker lever. It seated in the cylinder and could be removed after the inlet valve cage had been taken out

Fig. 395. The Renault 80-h.p. Engine.

The pistons were made of steel and fitted with three cast-iron rings. The connecting rods had "H" sections and were arranged side by side upon the crankpins. The intermediate crankshaft main bearings were plain and at the outer ends ball bearings were used. Pressure lubrication was maintained by a gear pump, and ignition was supplied by magnetos.

The 70-h p. model had a 94 mm. (3.78 in.) bore, 120 mm. (4.72 in.) stroke, and a total displacement of 423.76 cu. in. The weight was said to be 396 lbs., or 5.65 lbs. per rated h.p. The consumption of fuel and oil was reported as .64 and .045 lbs. per h.p-hr., respectively. The overall dimensions were as follows: length 45.5 in., width 29.8 in., and height 32.8 in.

The 75-h.p. Renault engine had a 100 mm. (3.94 in.) bore, 120 mm. (4.72 in.) stroke, and a total displacement of 460.4 cu. in. The weight was said to be 445 lbs., or 5.94 lbs. per rated h.p.

The 80-h.p. model had a 105 mm. (4.13 in.) bore, 130 mm. (5.12 in.) stroke, and 548.72 cu. in. total displacement. This engine had a compression ratio of 4 to 1, and was said to actually develop 88 h.p. at 1800 r.p.m. The fuel consumption was reported to be .772 lbs. per h.p-hr., and the oil consumption .066 lbs. per h.p-hr. Other than dimensions, the only important change in design was the use of articulated type connecting rods. As a result, corresponding cylinders in each row were arranged directly opposite. The weight was said to be 463 lbs., or 5.78 lbs. per rated h.p.

The 90-h.p. Renault air-cooled engine had twelve cylinders in 60 degree Vee arrangement. The bore was 90 mm. (3.54 in.), the stroke 140 mm. (5.51 in.), and the total displacement 650.76 cu. in. The weight was said to be 638 lbs., or 7.09 lbs. per rated h.p.

A slightly larger twelve-cylinder type was rated 100 h.p. at 1800 r.p.m. The bore and stroke were 96 mm. (3.78 in.) and 140 mm. (5.51 in.), respectively, and the total displacement was 741.96 cu. in. The weight was said to be 639 lbs., or 6.39 lbs. per rated h.p. The overall dimensions were as follows: length 56.3 in., width 32.3 in., and height 39.5 in.

Fig. 396. The Renault 100-h.p. Engine.

A twelve-cylinder Vee type engine, using the same cylinders and corresponding in design to the 80-h.p. model, was rated at 130 h.p. This engine was said to develop 138 h.p. at 1800 r.p.m. The compression ratio was 4 to 1, and the total displacement 823.08 cu. in. The fuel and oil consumption were reported as .76 and .066 lbs. per h.p-hr., respectively. As in the 80-h.p. model, the propeller speed was reduced to one-half engine speed, and articulated type connecting rods were employed. The weight was said to be 772 lbs., or 5.94 lbs. per rated h.p.

During the early part of the war a Renault series of water-cooled engines having 125 mm. (4.92 in.) bore and 150 mm. (5.91 in.) stroke were constructed in six, eight, and twelve-cylinder types.

The six-cylinder vertical engine, with a total displacement of 674.16 cu. in., was rated 130 h.p. at 1300 r.p.m. This engine was said to have been used only on caterpillars. It was arranged for direct driven propeller, and had a compression ratio of 4.25. The fuel consumption was reported to be .507 lbs., per h.p-hr., and the oil consumption .044 lbs. per h.p-hr. The weight was said to be 446 lbs., or 3.43 lbs. per rated h.p.

The cylinders were welded up in pairs from steel and encased in a common sheet-steel water jacket. The inlet and exhaust valves inclined in the cylinder head at 14 degrees to the vertical axis and were operated by rockers from an overhead camshaft. The crankshaft was carried in four plain bearings, and the connecting rods had "H" sections. Two Bosch ZR-6 magnetos and a duplex Zenith carburetor (Type 48DF) were fitted. Cast-iron pistons were used, and lubrication was by pressure and splash with gear pumps employed to scavenge and deliver fresh oil to the system.

The eight-cylinder model was arranged in 50 degree Vee form. This engine had a direct driven propeller, and was said to deliver 198 h.p. at 1550 r.p.m. The total displacement was 898.88 cu. in., and the compression ratio was 4.5. The complete weight was reported to be 474 lbs., or 2.39 lbs. per h.p.

The cylinders were the same as used on the six-cylinder model. The four-throw crankshaft was carried in three plain

Fig. 397. Transverse Section of Renault Twelve-Cylinder Engine.

bearings, and the connecting rods were of the articulated type. Both rods had "H" sections and the fork was integral with the master connecting rod. The pistons were made from an aluminum alloy.

The cooling water was circulated by a centrifugal pump having a single impeller and two outlets. The engine was equipped with a duplex Zenith carburetor and four S. E. V. four-cylinder magnetos which supplied dual ignition. Gear pumps delivered oil under pressure to the bearings, scavenged the sump, and supplied a certain quantity of fresh oil to the system. The fuel and oil consumption were reported as .53 and .055 lbs., per h.p-hr., respectively.

The twelve-cylinder model, with a total displacement of 1348.32 cu. in., was also in 50 degree Vee form. This engine

was said to deliver 285 h.p. at 1550 r.p.m., and employ a compression ratio of 4.6. The fuel consumption was reported as .518 lbs., per h.p-hr., and the oil consumption .055 lbs. per h.p-hr.

This engine resembled the eight-cylinder type in many details. The crankshaft, however, was supported in four plain bearings as in the six-cylinder type, and two centrifugal water pumps were used. Dual ignition was delivered by four S. E. V. six-cylinder magnetos, and the weight was said to be 836 lbs., or 2.93 lbs. per h.p.

Type 12-Fe was also a water-cooled twelve-cylinder 50 degree Vee type of 125 mm. bore and 150 mm. stroke. This engine was rated at 300 h.p., but was said to deliver 315 h.p. at 1550 r.p.m. and 327 h.p. at 1600 r.p.m. The compression ratio was 5 to 1. The complete weight was reported to be 794 lbs., or 2.64 lbs. per rated h.p.

Fig. 398. The Renault 300-h.p. Engine.

The cylinders were made up in pairs as in the other types, the inlet and exhaust valve each having a clear diameter of 61 mm. (2.4 in.), 45 degree seats, and a maximum lift of 10 mm. (.394 in.). The valve timing was as follows: the inlet opened 5 degrees and 55.3 minutes late and closed 45 degrees and 43.46 minutes late; the exhaust opened 48 degrees and 30.11 minutes early and closed 18 degrees and 50.77 minutes late. The use of one water pump with a single impeller and double outlets particularly distinguished this engine from the 285-h.p. model.

A twelve-cylinder Renault engine, having an angle of 47.5 degrees between each row of six, was built with individual cylinders of built-up steel and welded construction similar to those of the Mercedes. The bore was 125 mm. (4.92 in.), the stroke 160 mm. (6.3 in.), and the total displacement 1437.24 cu. in. The six-throw crankshaft was carried in four plain bearings, and the articulated type connecting rods had "H" sections. The pistons were made from cast iron and fitted with three rings. Dual ignition was supplied by four six-cylinder magnetos.

The later Renault engines, developed during the war, featured a new type valve gear. Four valves seating vertically in the cylinder head were operated from an overhead camshaft; the two inlets by a double rocker from one cam, and the two exhausts by single rocker arms from two cams. The camshaft and the oil tight housing which encased the valve gear were in one piece. The camshaft was driven by a vertical shaft and bevel gears, and the casing was bolted upon the cylinder heads.

The twelve-cylinder 60 degree Vee type, rated 258 h.p. at 2100 r.p.m., was used only as a tractor. The propeller speed was reduced in the ratio of 2 to 3 by spur gears. The bore and stroke were 150 mm. (4.13 in.) and 140 mm. (5.51 in.), respectively, and the total displacement was 885.72 cu.in. The compression ratio was 4.8, and the complete weight was said to be 470 lbs., or 1.82 lbs. per rated h.p. The approximate overall dimensions were as follows: length 42.95 in., width 24 in., and height 34.21 in.

Each pair of steel cylinders of built-up and welded construction was encased in sheet-steel water jackets. The

crankshaft was carried in four plain bearings, and the master and linked connecting rods each had tubular sections. The pistons were of aluminum alloy. The engine was fitted with duplex Zenith carburetors (Type QR) and two twelve-cylinder S. E. V. magnetos. Pressure lubrication was maintained by gear pumps, and a centrifugal pump with double delivery circulated the cooling water.

Fig. 399. Propeller End of Renault 410/420-h.p. Engine.

A twelve-cylinder 60 degree Vee type of 180 mm. (7.09 in.) bore and stroke, and 3359.04 cu. in. total displacement, was arranged for a direct driven propeller. This engine was rated at 400 h.p. and said to develop 404 h.p. at 1400 r.p.m. and 468 h.p. at 1700 r.p.m. The compression ratio was 5 to 1, and the weight, excluding the propeller hub, was said to be 925 lbs., or 2.31 lbs. per rated h.p.

The cylinders were constructed individually from steel with sheet-steel water jackets welded in place. The crank-

shaft was supported in seven plain bearings, and the articulated type connecting rods had tubular sections. Two Zenith carburetors were placed on each side of the engine, and four magnetos were arranged in two tiers at the rear end. Oil was delivered under pressure by a gear pump, similar pumps being employed for scavenging and supplying fresh oil to the system.

Fig. 400. Rear End of Renault 410/420-h.p. Engine.

A Renault twelve-cylinder 60 degree Vee type engine of 130 mm. (5.12 in.) bore, 140 mm. (5.51 in.) stroke, and 1360.32 cu. in. total displacement, was rated 410/420 h.p. at 2100 r.p.m. This engine was designed for tractor use only, the propeller speed being reduced in the ratio of 2 to 3 by spur gears. The propeller shaft was made hollow for the use of a 37 mm. cannon mounted in the Vee. The compression ratio was 5 to 1, and the complete weight was said to be 835 lbs.

The cylinders were constructed in the usual form of steel with welded on water jackets. Two inlet and two exhaust valves, vertically situated in the cylinder head, each had a clear diameter of 37 mm. (1.46 in.), a lift of 10.2 mm. (.402 in.), and 30 degree seats. The valve timing was as follows: the inlet opened 10 degrees late and closed 50 degrees late; the exhaust opened 56 degrees early and closed 10 degrees late.

The crankshaft was carried in seven plain bearings, and the articulated connecting rods were so arranged that the linked rod would lead and trail at alternate crank throws. The pistons were made of aluminum alloy. Two duplex carburetors in the Vee supplied the cylinders in sets of three, and the oil pumps were of the gear type. The fuel consumption was reported to be .528 lbs. per h.p-hr., and the oil consumption .055 lbs. per h.p-hr. Dual ignition was furnished by two twelve-cylinder S. E. V. magnetos.

Type 12-J. A twelve-cylinder 60 degree Vee type water-cooled engine of 130 mm. (5.12 in.) bore, 180 mm. (7.09 in.) stroke, and 1750.14 cu. in. total displacement, was said to deliver 425 h.p. at 1500 r.p.m. and 468 h.p. at 1750 r.p.m. The propeller was driven direct, and the compression ratio was 5 to 1. The weight was reported as 930 lbs.

Type 12-K-b. A slightly larger twelve-cylinder 60 degree Vee type water-cooled engine was rated 450 h.p. at 1600 r.p.m. The bore was 134 mm. (5.28 in.), the stroke 180 mm. (7.09 in.), and the total displacement 1862.88 cu. in. The weight was said to be 965 lbs., or 2.14 lbs. per rated h.p. The overall dimensions were as follows: length 78.74 in., width 37.4 in., and height 49.21 in.

Type 12-M. The largest twelve-cylinder Renault engine, rated at 500 h.p., was said to develop 550 h.p. at 1500 r.p.m. and 600 h.p. at 1650 r.p.m. The engine employed a direct driven propeller, and a compression ratio of 4.8 to 1. The bore and stroke were 150 mm. (5.91 in.) and 175 mm. (6.89 in.), respectively, and the total displacement was 2268.12 cu. in. The weight was reported to be 1168 lbs., or 2.33 lbs. per rated h.p. The approximate overall dimensions were as follows: length 71.08 in., width 30.7 in., and height 43.45 in.

R. E. P.

Air-cooled fan type engines were constructed by R. E. Pelterie in France as early as 1910. A five-cylinder engine, rated 20 h.p. at 1400 r.p.m., had an 85 mm. (3.35 in.) bore, 95 mm. (3.74 in.) stroke, and a total displacement of 164.8 cu. in. The cylinders were made from cast iron with integral cooling fins, and were so staggered that all five operated about a single-throw crankshaft. The complete weight of this engine was stated to be 82.5 lbs., or 4.12 lbs. per rated h.p.

Fig. 401. The R. E. P. Five-Cylinder Fan Type Engine.

A seven-cylinder fan type, with cylinders of the same dimensions and therefore having a total displacement of 230.72 cu. in., was rated 30 h.p. at 1400 r.p.m. Four cylinders were forward and three to the rear, each with articulated connecting rod assemblies which worked upon a two-throw crankshaft. The weight was stated to be 114.5 lbs., or 3.81 lbs. per rated h.p.

A ten-cylinder fan type engine, a double form of the 20-h.p. model and having a total displacement of 329.6 cu. in., was rated 40 h.p. at 1400 r.p.m. This engine employed a two-throw crankshaft, and was fitted with a double magneto and two carburetors. The weight was said to be 158.5 lbs., or 3.96 lbs. per rated h.p.

The double form of the 30-h.p. model, with fourteen cylinders and a total displacement of 461.44 cu. in., was rated 60 h.p. at 1400 r.p.m. and said to weigh 216 lbs., or 3.6 lbs. per rated h.p.

Fig. 402. Transverse Section of R. E. P. Seven-Cylinder Engine.

Fig. 403. Longitudinal Section of R. E. P. Seven-Cylinder Engine.

An R. E. P. seven-cylinder air-cooled radial engine, constructed later, was rated 95 h.p. at 1100 r.p.m. The bore was 110 mm. (4.33 in.), the stroke 160 mm. (6.3 in.), and the total displacement 649.39 cu. in. The weight was reported to be 462 lbs., or 4.86 lbs. per rated h.p.

REX

The Rex was a single valve air-cooled rotary engine built in Germany for use in light aircraft.

RHEINISCHE

The vertical water-cooled engines built at the Rheinische Aero Works of Euskirchen, Germany, had a bore of 120 mm. (4.72 in.) and a stroke of 140 mm. (5.51 in.). The four-cylinder model, of 385.64 cu. in. total displacement, was rated 70 h.p. at 1250/1300 r.p.m. and said to weigh 280 lbs., or 4 lbs. per rated h.p. The six-cylinder engine was rated 100 h.p. at 1250 r.p.m. The total displacement was 578.46 cu. in., and the weight was reported to be 415 lbs., or 4.15 lbs. per rated h.p.

The cylinders had welded on sheet-metal water jackets and overhead valves operated by means of push rods and rockers. Dual ignition was supplied by two Bosch magnetos, and a Bosch electric starter was fitted for starting purposes.

Fig. 404. The Six-Cylinder 100-h.p. Rheinische Engine.

Lubrication was by a force-feed circulating system with a fresh oil addition supplied by a pump. The oil supply was carried in the lower-half crankcase.

The Rheinische Works also built a three-cylinder air-cooled fan type engine. The bore was 105 mm. (4.13 in.), the stroke 130 mm. (5.12 in.,), and the total displacement 205.77 cu. in. This engine was rated 35 h.p. at 1350 r.p.m. and said to weigh nearly 100 lbs.

Fig. 405. The Rheinische Three-Cylinder Fan Type Engine.

Their five-cylinder air-cooled radial design, of the same cylinder dimensions and 342.95 cu. in. total displacement, was rated at 50/60 h.p. It was said to develop 58 h.p. at 1350 r.p.m. and weigh approximately 210 lbs., or 3.79 lbs. per h.p.

The valves were operated by a three-cam disc through push rods and rockers; the exhaust valves were situated in front. Oil was led through the hollow crankshaft to the crankpin bearing and from there to the piston pins through the hollow connecting rods. The rear bearing was supplied by a separate pressure line. The gas was conducted to the cylinders through pipes which communicated with a ring-shaped induction passage in the rear of the crankcase.

RHENANIA

The Rhenania Motor Works of Mannheim, Germany, have constructed air-cooled rotary engines.

RICARDO

At least four British airplane engines have been designed or re-designed to embody the Ricardo system of super-charging. Among these the best known is the B. H. P. design which was produced experimentally during 1916 and 1917. This engine has been flown but the results apparently did not warrant further development.

Fig. 406. The B. H. P. Engine with Ricardo Supercharger.

A Brotherhood design to develop around 600 h.p. was built during 1914-1915 under orders from the British Admiralty. The development of this engine was later abandoned and it is not known to have ever been used in flight.

The twelve-cylinder 45 degree Vee type engine built by Armstrong-Whitworth and known as the R. H. A. was designed to operate on the Ricardo principle. This engine was flown at Farnboro, but its performance and constructional details have never been disclosed.

Contrary to the wishes of Rolls-Royce, a "Hawk" model with a Ricardo supercharger was also ordered to be built. The tests of this engine did not show the performance anticipated so the project was abandoned.

RICHARD AND HERING

Richard and Hering (Rex-Simplex Automobile Works) in Germany at one time constructed airplane engines of their own design, but have since abandoned them, according to reports.

ROBERTS

The Roberts airplane engines, all operated on the two-stroke cycle. These engines were built by the Roberts Motor Company of Sandusky, Ohio, (now operating as the Roberts Motors) from the designs of Mr. E. W. Roberts, a pioneer gas engine designer who, during 1894-95, was assistant to Mr. Hiram Maxim.

One of the first Roberts two-cycle engines, built during 1911-12, was a four-cylinder vertical water-cooled type of 4.5 in. bore, 5 in. stroke, and 318 cu. in. total displacement. The output was said to be 50 h.p. at 1400 r.p.m., and the weight 170 lbs., or 3.4 lbs. per h.p. The overall dimensions were as follows: length 40.5 in., height 25 in., and width 24 in.

Fig. 407. The Roberts 75-h.p. Two-Cycle Engine.

The cylinders were cast from a material known as Aerolite. The water-jacket was partly cored out of the casting and the remainder covered by an aluminum jacket caulked into grooves in the cylinder. These engines were of the usual

three-port type except that the opening for admission and exhaust was by a spiral tubular rotary valve instead of by means of the piston. A cellular by-pass was provided to prevent back firing or explosions in the crankcase.

The pistons and rings were made from cast iron. Ignition was by a Bosch magneto provided with a helical gear for turning the armature to advance and retard the spark. The mixture was supplied by a Kingston carburetor, and lubrication was by splash.

A six-cylinder engine of similar design and with the same bore and stroke, had a total displacement of 477 cu. in. This engine was rated at 75 h.p. and said to weigh 243 lbs., or 3.24 lbs. per rated h.p. The overall dimensions were as follows: length 52.5 in., width 24 in., and height 25 in.

Fig. 408. Side View of Roberts 100-h.p. Engine.

Model 6X. A six-cylinder vertical Roberts engine of 5 in. bore and stroke, was reported to develop 100 h.p. at 1200 r.p.m. The weight was said to be 350 lbs., or 3 5 lbs. per h.p. The fuel consumption was reported as .63 lbs. per h.p-hr., and the oil consumption as .047 lbs. per h.p-hr.

The cylinders were cast separately from grey iron with water jackets integral. The pistons were made from aluminum and fitted with three rings, one below the piston pin. The crankshaft was supported in seven plain bearings, and the connecting rods had "H" sections. Two 2 in. Panhard carburetors supplied three cylinders each, and the ignition was by either one or two Bosch magnetos.

There has been reported a Roberts six-cylinder vertical engine rated 100 h.p. at 1200 r.p.m. of 5 in. bore, 5.5 in. stroke, and 647.94 cu. in. total displacement. The weight was said to be 368 lbs., or 3.68 lbs. per rated h.p.

Model 6XX. A six-cylinder vertical engine, known as Model 6XX, was rated 200 h.p. at 1400 r.p.m. The bore was 6.5 in., the stroke 6 in., and the total displacement 1194.59 cu. in. The fuel consumption was reported to be .63 lbs. per h.p-hr., and the oil consumption .047 lbs. per h.p-hr. The weight was said to be 690 lbs., or 3.45 lbs. per rated h.p.

Fig. 409. End View of Roberts 100-h.p. Engine.

Model E-12. A twelve-cylinder Vee type Roberts engine, known as the Model E-12, was rated 350 h.p. at 1200 r.p.m. The bore was 6 in., the stroke 6.5 in., and the total displacement 2205.36 cu. in. The crankshaft had thirteen bearings. The weight was said to be 990 lbs., or 2.82 lbs. per rated h.p.

ROBINSON

The Robinson engine was a six-cylinder air-cooled radial type, rated at 100 h.p. The bore was 5 in., the stroke 6 in., and the total displacement 706.86 cu. in. The weight was reported to be 300 lbs., or 3 lbs. per rated h.p. This engine was used in a monoplane designed by William C. Robinson and built by the Grinnell Aeroplane Co. of Grinnell, Iowa.

ROLLS-ROYCE

Messrs. Rolls-Royce began the design and development of airplane engines in 1914. Among the early designs, of which several were built and tested, was an eight-cylinder vertical water-cooled engine rated at 90 h.p. Production on the first series of "Eagle" types started in 1915 and was shortly followed by the construction of the "Falcon" and "Hawk" models. The largest Rolls-Royce engine, the "Condor," was completed just before the Armistice.

"Eagle." The Rolls-Royce "Eagle" is a water-cooled twelve-cylinder 60 degree Vee type engine of 4.5 in. bore, 6.5 in. stroke, and 1240.56 cu. in. total displacement.

The cylinders are machined from steel forgings and have spherical shaped combustion chambers in which the valves seat in an inclined position. The water jackets are made in pairs from pressed steel and welded in place. The forged steel

Fig. 410. Transverse Section of Rolls-Royce "Eagle."

ports are welded to the heads, but the joint is made higher than the usual practice in order to facilitate welding and incidently prevent the accumulation of material near the valve seat.

The inlet and exhaust valves are of tulip form and interchangeable. The valve diameter is 2 in., the lift .43 in., and

the angle of the seats 30 degrees. The timing of the valves is as follows: the inlet opens 10 degrees late and closes 54 degrees late; the exhaust opens 58 degrees early and closes 10 degrees late.

Pistons of the Zephyr type are made from aluminum with the piston pin bosses located unusually low on the skirt and free from that section which carries the rings in order to allow for expansion without deformation. There are three top rings and a lower ring which serves as an oil scraper. The position of each ring is maintained by a pin secured into the piston by a nut. The piston pin is secured to prevent lateral movement and rotation and bears in the piston without bushings.

Fig. 411. Longitudinal Section of Rolls-Royce "Eagle."

The six-throw crankshaft is supported by seven bearings with individual caps. The early Marks were balanced by forged-steel counterweights separately attached. The crank-pins have four oil holes equi-distant around the circumference. A flange is provided for attaching the internal gear of the epicyclic reduction gear system which is common to most Rolls-Royce engines.

The connecting rods are of the articulated type with "H" sections. The master rod carries a fork for attaching the linked rod, and the cap joint is at an angle of 38 degrees to a line perpendicular to the axis. Both rods have pipes clipped in place which carry oil to the piston pin bearings. The babbitt of the crankpin bearing is applied directly to the rod.

Fig. 412. Rear View of Rolls-Royce "Eagle."

The lubricating system is of the pressure-feed dry-sump type. Oil is drawn from the tank by a gear pump, which delivers at 40 lbs. pressure to the bearings past a pressure relief valve, and contains another set of gears which scavenge the drainage in the crank-chamber through a strainer located at the center and lowest part of the sump. The fuel feed is provided by a piston type air pump. The cooling water is circulated by a centrifugal pump arranged for admission on both sides of the impeller. This reduces the possibilities of leakage to a minimum, only one packing joint being required and that on the suction side of the pump.

The overhead camshaft is driven by vertical driveshaft and bevel gears. The camshaft housing extends over six-cylinders in one section, and is provided with slots through

which the valve rockers operate. The drive of the camshaft and accessories is taken through a coupling which damps the vibrations of the crankshaft. The magnetos are mounted crosswise at the anti-propeller end of the engine.

The crankcase is made from aluminum and provided with four studs for the mounting of each cylinder. The concentric gear housing is attached by flange and screws. The total dry

Fig. 413. Propeller End of Rolls-Royce "Eagle."

weight of the engine is reported to be 900 lbs., and without reduction gear 836 lbs. The water content of the engine is 3.1 gallons. The approximate overall dimensions are as follows: length 63.25 in., width 32 in., and height 39 in.

Each change in design involving the use of non-interchangeable parts was represented by a new series in which a gain in performance was usually effected.

Series I gave a normal output of 240 h.p. at 1600 engine r.p.m. and 1024 propeller r.p.m., the gear ratio being .64. The salient design features were six-cylinder inlet manifolds, two single 36 mm. Claudel carburetors, and two magnetos.

Series II gave a normal output of 260 h.p. at corresponding speeds with four of the same carburetors attached to three-cylinder inlet manifolds.

Series III, although in general following the Series II design, showed a normal output of 270 h.p.

Series IV varied from the preceding series principally in the substitution of two 38 mm. duplex Claudel carburetors.

Series V operating at the same normal speed gave 285 h.p. Four carburetors were again employed, but were increased in size to 38 mm.

Series VI had a normal output of 308 h.p. at 1650 engine r.p.m. and 990 propeller r.p.m., the gear reduction ratio having been changed to .6. The other important change was increasing the number of magnetos to four.

Series VII closely followed the Series VI design and had the same normal power output.

Series VIII, using a 5.3 compression ratio, gave 360 h.p. at 1800 r.p.m. The normal speed of the propeller with .6 gear ratio was 1080 r.p.m. Four 42 mm. Claudel carburetors were attached to four three-cylinder inlet manifolds of new design.

A few special "Eagle" engines were built which gave over 400 h.p. These employed new camshafts with high lift cams.

"Falcon." The Rolls-Royce "Falcon" is similar in construction to the "Eagle" engines, being a water-cooled twelve-cylinder 60 degree Vee type of 4 in. bore, 5.75 in. stroke, and 867 cu. in. total displacement. The epicylic reduction gears have a ratio 56/95 or .589. The total dry weight including gear reduction is said to be 686 lbs., and the water content of the engine 2.5 gallons. All engines of the "Falcon" series are equipped with two magnetos and three-cylinder inlet manifolds.

Series I engines develop 218 h.p. at 1700 engine r.p.m. and 1003 propeller r.p.m. Two duplex Claudel 34 mm. carburetors are employed.

Series II, at 2000 engine r.p.m., develops 250 h.p. The duplex carburetor is increased in size to 36 mm.

Series III employs four single 38 mm. Rolls-Royce Claudel-Hobson carburetors and larger three-cylinder inlet manifolds of later design. It develops 275 h.p. at 2000 r.p.m. The best performance obtained with a "Falcon" engine is over 300 h.p.

"Hawk." The Rolls-Royce "Hawk" is a six-cylinder vertical water-cooled engine with direct driven propeller. The bore is 4 in., the stroke 6 in., and the total displacement 452.38 cu. in. The total dry weight is said to be 405 lbs., and the water content 1.4 gallons. The overall dimensions are as follows: length 46.75 in., width 23 in., and height 28.75 in.

Individual cylinders of steel construction each have one spark plug supplied by a single magneto. Two single Claudel carburetors of 28 mm. are separately attached to a pair of three-cylinder inlet manifolds. Series I, at a normal engine speed of 1350 r.p.m., is said to give 85 h.p.; and Series II, at 1500 r.p.m., from 90 to 100 h.p.

Fig. 414. The Rolls-Royce "Condor" Engine.

"Condor." The Rolls-Royce "Condor" was developed for long distance bombing flights. There are twelve individual steel cylinders in 60 degree formation of 5.5 in. bore and 7.5 in. stroke, giving the engine a total displacement of 2138.4 cu. in. At 1650 r.p.m. the rated output is 540 h.p., and at 1750 r.p.m. it is 600 h.p. The best performance is said to be 660 h.p. The engine is built with epicyclic reduction gears in two ratios, .666 and .554. The dry weight with the former gear reduction is said to be 1300 lbs., and with the latter 1440 lbs. Five gallons of water are carried in the jackets and piping. The approximate overall dimensions are as follows: length 71 in., width 33 in., and height 42 in.

Fig. 415. End View of Rolls-Royce "Condor."

Both brazed on copper water jackets and welded on sheet-steel water jackets have been tried. The combustion chamber is spherical in form and the four valves normal to the surface require the design of a rather unconventional operation mechanism. An overhead enclosed camshaft with three cams per cylinder extends over six cylinders and is driven by a vertical driveshaft and bevel gears. The carburetors are situated on the outside. A large induction pipe leads from each carburetor to a six cylinder inlet manifold in the Vee. A centrifugal water pump mounted underneath has four outlets, one to each three-cylinder group. The ignition is furnished by two magnetos mounted crosswise at the end of the engine.

ROMEO

A twelve-cylinder 60 degree Vee type water-cooled engine, rated at 600 h.p., has been built experimentally in Italy.

ROSSEL-PEUGEOT

The Rossel-Peugeot engines were built in France during 1913 and 1914. A four-cylinder vertical water-cooled type, rated 100 h.p. at 1300 r.p.m., had a 140 mm. (5.51 in.) bore and stroke, and a total displacement of 525.56 cu. in. This engine was reported to weigh 352 lbs., or 3.52 lbs. per rated h.p.

Seven-cylinder air-cooled rotary types were constructed in 30, 40, and 50-h.p. sizes. The 30-h.p. engine, which operated normally at 1100 r.p.m., had a 109 mm. (4.29 in.) bore, 110 mm. (4.33 in.) stroke, and a total displacement of 438.13 cu. in. The weight was stated to be 165 lbs., or 5.5 lbs. per rated h.p.

A 40-h.p. engine, operating at the same normal speed, had a 110 mm. (4.33 in.) bore and stroke, and a total displacement of 446.32 cu. in. This engine [illegible] tated to weigh 172 lbs., or 4.3 lbs. per rated h.p.

The 50-h.p. model of corresponding dimensions operated at a normal speed of 1150 r.p.m., and was reported to weigh 165 lbs., or 3.3 lbs. per rated h.p.

RUSTON-PROCTOR

The Ruston-Proctor engine was an experimental air-cooled geared rotary type, which operated on the six-stroke cycle, and was rated at 200 h.p.

SALMSON

The Salmson engines, designed and patented by Canton and Unné, were built in France by the Société Anonyme des Moteurs Salmson of Billancourt, Seine, and in Great Britain by the Dudbridge Iron Works, Ltd., of Stroud, Gloucester. No other water-cooled radial engine has been more thoroughly developed than the Salmson designs. Salmson airplanes equipped with Salmson engines were successfully used in large numbers by the French and American Armies during the war.

Barrel Type. One of the Salmson engines diverging from the usual radial design was a 55-h.p. water-cooled stationary barrel type of seven cylinders. Two pistons, in each of the cylinders lying parallel to the central shaft, had a common combustion chamber that was supplied with one spark plug and one set of valves.

Fig. 416. Salmson Seven-Cylinder Barrel Type Engine.

Water-Cooled Radials. Among the features characteristic of many of the early Salmson radial models was the steel water-cooled cylinder construction using spun copper water jackets brazed in place. The cast-iron pistons were usually fitted with three rings, and the aluminum crankcase was in halves that joined in the plane of the cylinders and securely clamped them in place.

The crankshaft was in two sections, a short taper on the end of the crankpin being held in one of the crank-throws by a key and nut, and ball bearings were used in its mounting as well as for all other rotating parts. The connecting rods had "H" sections, and were hinged on a non-oscillating carrier which effected a circular path for each of big ends. This carrier had a gear meshing with one of the gears carried on a spindle bearing in an extension of the crank-cheek. Another gear on the other end of the spindle meshed with a gear centrally fixed to the crankcase.

The valves were generally placed vertically in the cylinder head and operated by means of tappets, push rods, and rockers. Separate cams for each pair of valves were keyed to a sleeve driven at half engine speed by a train of gears. The cam roller followers were situated at the outer ends of a centrally pivoted lever and successively lifted the tappets of each valve in the course of the cam's rotation, hence the opening period of the inlet and exhaust valves was the same.

M-7. The M-7 model was a seven-cylinder engine of 120 mm. (4.72 in.) bore, 140 mm. (5.51 in.) stroke, and 674.87 cu. in. total displacement. At 1250 r.p.m., the normal output

was 90 h.p. The fuel consumption was said to be .53 lbs. per b.h.p-hr., and the weight 375 lbs., or 4.16 lbs. per h.p.

M-9. A nine-cylinder engine, using the same cylinders and therefore of 867.69 cu. in. total displacement, was rated 130 h.p. at 1250 r.p.m Some of the tests that were reported showed the output to be 110 h.p. at 1280 r.p.m. The consumption of fuel and oil was said to be .61 and .059 lbs. per h.p-hr., respectively. The highest weight reported, including radiator, was 465 lbs., 4.23 lbs. per actual h.p.

Fig. 417. The Salmson Nine-Cylinder 110-h.p. Engine.

2M-7. An engine composed of two seats of M-7 cylinders operating on the six-stroke cycle was said to deliver 200 h.p. at 1250 r.p.m. This engine had a single-throw crankshaft and a specially arranged gear providing for the rotation of the cams at one-third crank speed. The fuel consumption was reported to be .53 lbs. per h.p hr., and the oil consumption .7 lbs. per h.p-hr. The total displacement was 1349.74 cu. in., and the weight of the engine and radiator was stated to be 935 lbs., or 4.67 lbs. per h.p.

Other Salmson engines corresponding to the above M types and with 2 mm. larger bore are also reported to have

been built. These engines measured 41.3 in. overall diameter.

R-9. A nine-cylinder engine of 125 mm. (4.92 in.) bore, 140 mm. (5.51 in.) stroke, and 942.75 cu. in. total displacement, was rated at 155 h.p. and said to deliver 160 h.p. at 1300 r.p.m. The fuel consumption was reported to be .5 lbs per h.p-hr., and the weight complete with radiator 704 lbs. The overall diameter was 42.5 in.

Fig. 418. The Salmson 230-h.p. Engine.

A-9. The A-9 model was rated at 230 h.p. and said to develop 240 h.p. at 1280 r.p.m. This was a nine-cylinder water-cooled radial engine of 140 mm. (5.51 in.) bore, 170 mm. (6.69 in.) stroke, and 1435.68 cu. in. total displacement. The fuel consumption was said to be .5 lbs. per h.p-hr., and the weight complete with radiator 968 lbs. The overall diameter was 46.5 in.

Z-9. The Z-9 model was developed during the war. This engine had nine cylinders of 125 mm. (4.92 in.) bore, 170 mm. (6.69 in.) stroke, and 1146.42 cu. in. total displacement. The compression ratio was 5.4, and the output 230 h.p. at 1500 r.p.m. and 280 h.p. at 1650 r.p.m. The consumption of fuel and oil was .495 and .077 lbs. per h.p-hr., respectively. The weight was stated to be 473 lbs.

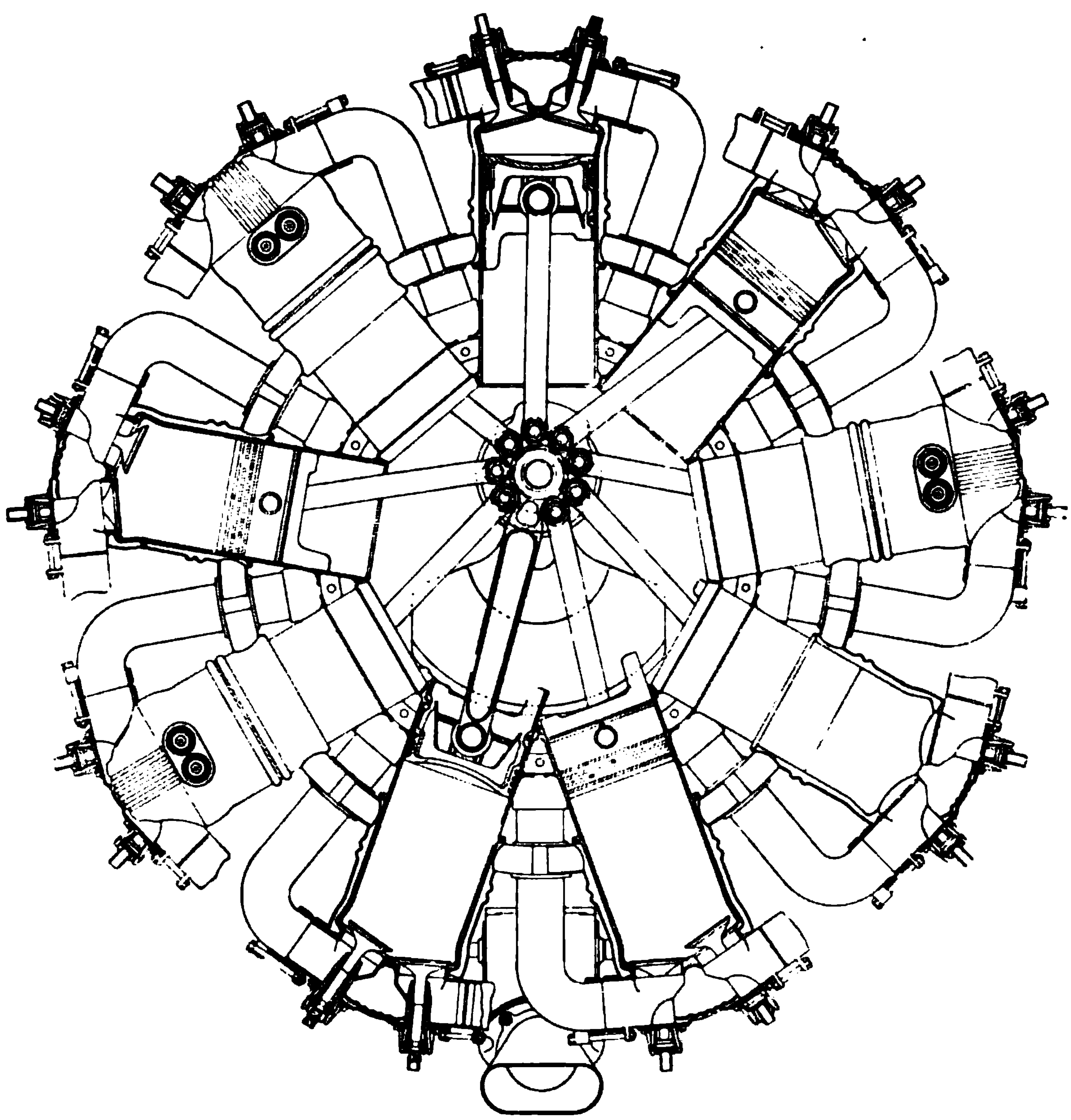


Fig. 419. Transverse Section of Salmson Z-9 Engine.

In the later types, articulated connecting rods were introduced in place of the non-oscillating carriers. The master rod had an "H" section, and the linked rods were of tubular section. The single-throw crankshaft was made in two sections and joined in the same manner as the earlier types. The pistons were made of aluminum and fitted with four top rings and a lower oil scraper ring.

Fig. 420. Longitudinal Section of Salmson Z-9 Engine.

The steel cylinders had welded on sheet-steel water jackets, and were held between the two sections of the crank-case by flanges both inside and out. Wedging rings on the

exterior were used to pull the cylinder up tightly against the crankcase. The inlet and exhaust valves were slightly inclined in the cylinder head, and operated through push rods and rockers by three inlet and three exhaust cams turning in the direction of the crankshaft at one-fourth its speed. The valve timing was as follows: the inlet opened on top center and closed 55 degrees late; the exhaust opened 65 degrees early and closed on top center.

Dual ignition was supplied by two nine-cylinder magnetos. Claudel or Zenith duplex carburetors furnished the mixture. The oil was circulated by two oscillating plunger pumps; the small plunger forced oil to the bearings under pressure and the large one was used for scavenging.

Z-18. A double form of the Z-9 model, with eighteen-cylinders of 2292.84 cu. in. total displacement, was normally rated 500 h.p. at 1600 r.p.m and 560 h.p. at 1700 r.p.m. The compression ratio was 5.4. The fuel consumption was said to be .485 lbs. per h.p-hr., and the oil consumption .086 lbs. per h.p-hr. The weight was stated to be 1000 lbs., and the overall diameter 39.5 in.

A-Z-9. A nine-cylinder engine of 140 mm. (5.51 in.) bore, 170 mm. (6.69 in.) stroke, and 1435.68 cu. in. total displacement, was rated at 300 h.p. This engine was of the same dimensions as the A-9 model, but followed more closely the design of the Z types. The cylinders, however, were bolted to the crankcase, and had four valves.

Horizontal Radials. Included among the early Salmson engines were water-cooled radial types with cylinders in the

Fig. 421. Salmson Horizontal Radial Engine.

horizontal plane. These engines were often used in dirigibles and sea-planes. An engine of this type, besides lending itself conveniently to installation, affords better visibility and diminishes head resistance. The propeller drive was through bevel gears which usually reduced the speed in the ratio of 9 to 5.

B-9. The Model B-9 was a nine-cylinder water-cooled horizontal radial type, rated 140 h.p. at 1250 r.p.m. The bore was 120 mm. (4.72 in.), the stroke 150 mm. (5.91 in.) and the total displacement 930.69 cu. in.

D-9. A larger nine-cylinder horizontal radial type, known as Model D-9, was rated 300 h.p. at 1200 r.p.m. The bore was 150 mm. (5.91 in.), the stroke 210 mm. (8.27 in.), and the total displacement 1945.62 cu. in. The weight was reported to be 990 lbs., or 3.3 lbs. per rated h.p.

2D-9. An eighteen-cylinder engine, a double form of D-9 model and with 3891.24 cu. in. total displacement, was rated 600 h.p. at 1200 r.p.m. The weight was said to be 2460 lbs., or 4.1 lbs. per rated h.p.

Fig. 422. The Salmson Air-Cooled Radial Engine.

Air-Cooled Radials. Since the war, the Salmson company have also undertaken the design and development of air-cooled radial engines.

9-R-A. The first Salmson nine-cylinder air-cooled radial engine was rated at 220 h.p. and said to develop 230 h.p. at 1500 r.p.m The bore was 125 mm. (4.92 in.), the stroke 170 mm. (6.69 in.), and the total displacement 1146.42 cu. in. The weight was reported to be approximately 500 lbs., or 2.27 lbs. per rated h.p.

The cylinders were made from aluminum and had screwed in steel liners. An inlet and exhaust valve in the cylinder head were each operated by means of a push rod and rocker arm.

The Salmson Company has also experimented with an eleven-cylinder air-cooled radial design, rated at 280 h.p. The bore was 105 mm. (4.13 in.), the stroke 160 mm. (6.3 in.), and the total displacement 928.29 cu. in. The weight was estimated to be 374 lbs., or 1.34 lbs. per rated h.p.; and the overall diameter was said to be 59 in.

SCHROETER

The Schroeter was a six-cylinder vertical water-cooled engine of 124 mm. (4.88 in.) bore, 160 mm. (6.3 in.) stroke, and 707.1 cu. in. total displacement, rated 89 h.p. at 1250 r.p.m.

SCHWADE

Otto Schwade and Company of Erfurt, Germany, built the Stahlherz engines, which were copied from the Gnome.

SEGA

The Sega is a seven-cylinder air-cooled rotary engine in which the cylinders oscillate on trunions that are mounted on a steel ring carried from the bearings on the crankcase by radial arms. The interior of the crankcase is exposed, consequently the aluminum pistons which are rigidly attached to the connecting rods, are air-cooled. In addition to the single inlet and exhaust valves, located in the side of the cylinder, are auxiliary exhaust ports which are uncovered near the end of the exhaust stroke.

Fig. 423. The Sega Rotary Engine.

SHIMADZU

Two Shimadzu engines were entered in the contest held by the Imperial Aviation Association of Japan on June 22, 1917. A nine-cylinder air-cooled rotary type, which was a close copy of the Gnome, was rated 80 h.p. at 1200 r.p.m. The bore was 105 mm. (4.13 in.), the stroke 140 mm. (5.51 in.), and the total displacement 664.29 cu. in. The weight was stated to be 298 lbs., or 3.72 lbs. per rated h.p. This engine ran about four hours during the tests and won the $10,000 prize.

The other engine was an eight-cylinder air-cooled Vee type, rated 90 h.p. at 1800 r.p.m. This engine failed completely after about two minutes running. The bore and stroke were 4.5 in., and the total displacement 572.56 cu. in. The weight was reported to be 497 lbs., or 5.52 lbs. per rated h.p.

S. H. K.

The four S. H. K. air-cooled rotary engines, exhibited at the Paris Show of 1913, were constructed entirely of steel. The cylinders had circumferential cooling flanges, and were secured to the crankcase by a means of a gland that screwed into the case on a flange formed at the base of the cylinder. The cylinders were then held tightly in place by a locking ring.

The connecting rods were attached to the crank by feet to which bronze shoes were riveted. Two "U" shaped rings encircled the lateral extensions along the shaft and secured them in position. No piston rings were used, gas tightness being effected by three shallow grooves around the piston.

The crankshaft was built up from two parts, and fitted with ball bearings to support the rotating mass of crankcase and cylinders. Valves of the concentric type were operated by a single push rod. A plunger pump delivered oil under pressure to the crankpin, cams, and gears; and a high-tension magneto furnished the ignition.

Fig. 424. The S. H. K. 70-h.p. Rotary Engine.

A seven-cylinder S. H. K. engine, rated 70 h.p. at 1200 r.p.m., had a 110 mm. (4.33 in.) bore, 140 mm. (5.51 in.) stroke, and a total displacement of 567.98 cu. in. The weight was said to be 154 lbs., or 2.2 lbs. per rated h.p. A double form, with 1135.96 cu. in. displacement, was rated 140 h.p. at 1200 r.p.m. This engine was said to weigh 308 lbs. or 2.2 lbs. per rated h.p.

A seven cylinder engine, rated 90 h.p. at 1200 r.p.m., had a 124 mm. (4.88 in.) bore, 140 mm. (5.51 in.) stroke, and a total displacement of 722.75 cu. in. The weight was said to

be 198 lbs., or 2.2 lbs. per rated h.p. A double form of fourteen cylinders, with a total displacement of 1445.5 cu. in., was rated 180 h.p. at 1200 r.p.m.; and was said to weigh 396 lbs., or 2.2 lbs. per rated h.p.

SIDDELEY

The Siddeley-Deasy Motor Car Company, Ltd., which is now the Armstrong-Siddeley Motors, Ltd., of Coventry, England, produced a B. H. P. design, known as the "Puma," in large quantities during the latter part of the war. Late in 1917 the company was approached by the Air Board in regard to an engine of not less than 600 h.p. at 1500 r.p.m This design became known as the "Tiger." The air-cooled radial engines manufactured by Armstrong-Siddeley are described elsewhere.

Fig. 425. Exhaust Side of Siddeley "Puma" Engine.

"Puma." The Siddeley "Puma" engine is a water-cooled six-cylinder vertical type of 145 mm. (5.71 in.) bore, 190 mm. (7.48 in.) stroke, and 1149.24 cu. in. total displacement. The engine normally develops 209 h.p. at 1250 r.p.m. and a maximum of 240 h.p. at 1560 r.p.m. The brake mean effective pressure at 1250 r.p.m. is 115.5 lbs. per sq. in., and the maxi-

mum, which is developed at 1050 r.p.m., is approximately 120 lbs. per sq. in. The compression ratio is 4.96. The dry weight is said to be 648 lbs., or 3.1 lbs. per h.p.; and the water content of the engine is approximately 36 lbs. The overall dimensions are as follows: length 70 in., width 24.125 in., and height 42.625 in.

The cylinders are constructed in blocks of three. Steel sleeves, open at both ends, are screwed into an aluminum casting which forms the heads for three cylinders and the inlet manifold. The separate aluminum water jacket, which surrounds the cylinder barrels, is bolted to the head casting and

Fig. 426. The Siddeley "Puma" Engine.

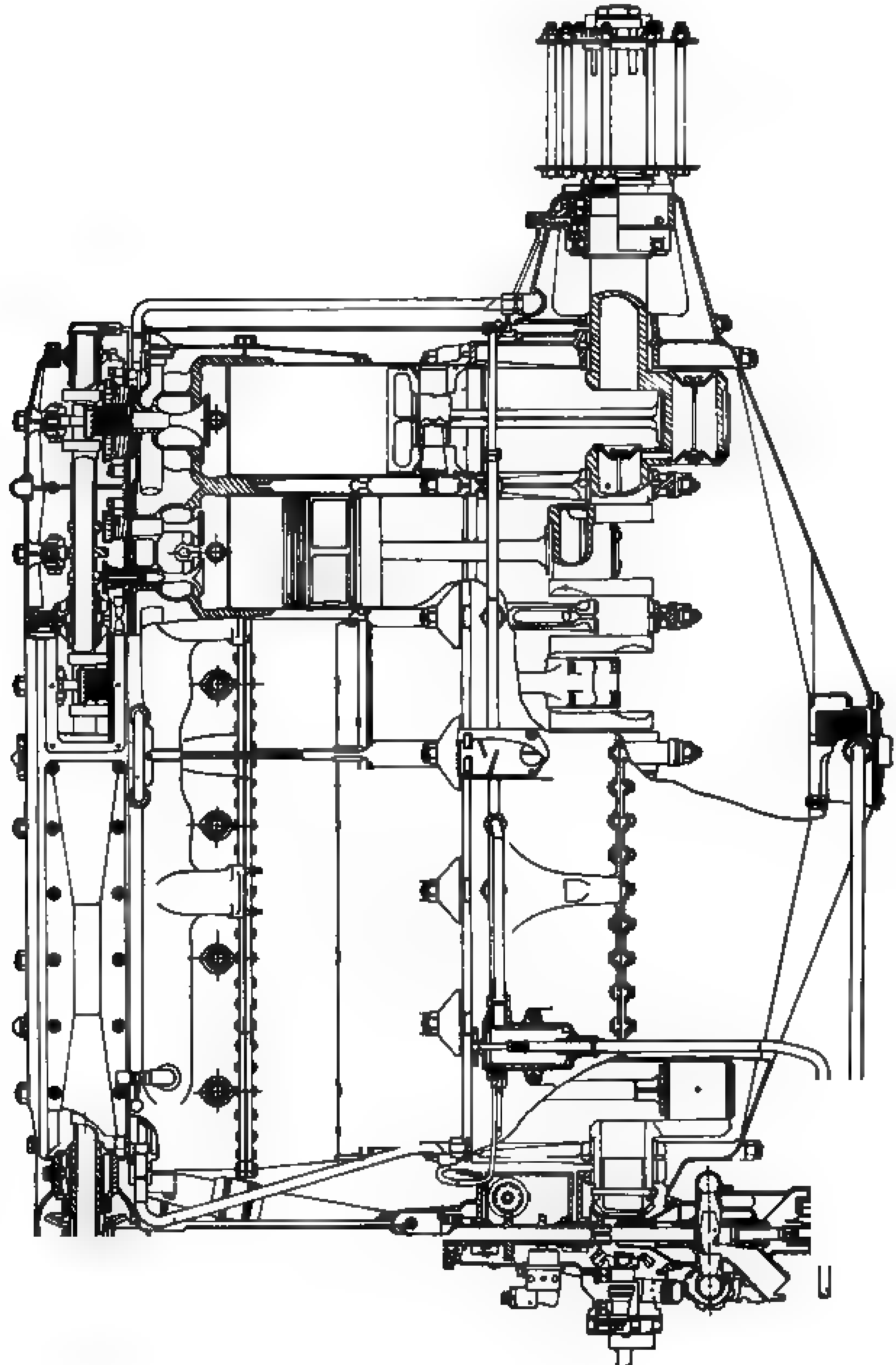


Fig. 427. Longitudinal Section of Siddeley "Puma" Engine.

Fig. 428. Transverse Section and End View of Siddeley "Puma" Engine.

made tight at the bottom by annular nuts screwed against rubber glands. The bronze valve seats are expanded into place.

There are two exhaust valves and one inlet valve standing vertically in the cylinder head. An overhead camshaft, enclosed by an oil tight housing, operates directly upon the exhaust valves and the inlet by means of a rocker arm. The clear diameter of the inlet valve is 66 mm. (2.598 in.), and the lift 11.2 mm. (.441 in.). The clear diameter of the exhaust valves is 44 mm. (1.732 in.), and the lift 9.5 mm. (.374 in.). Both valves have 45 degree seats. The valve timing is as follows: the inlet opens 7 degrees late and closes 43 degrees late; the exhaust opens 58 degrees early and closes 12 degrees late.

Two Zenith carburetors having 36 mm. chokes are bolted to the inlet manifold flange on the cylinder head. Lubrication is of the dry-sump pressure-feed type, an oil pressure of 15 to 20 lbs. being maintained by a gear pump. The fuel consumption is said to be .519 lbs. per h.p-hr., and the oil consumption .045 lbs. per h.p-hr.

The crankshaft is carried in seven plain bearings, and the connecting rods have "H" sections and four-bolt caps. The pistons are made from aluminum and fitted with four rings, the lower top ring and the one below the wrist pin being used as oil scrapers. Dual ignition is supplied by two Fellows EM-6 magnetos that are mounted crosswise and driven from the vertical driveshaft for the camshaft.

Fig. 429. End View of Siddeley "Tiger."

"Tiger." The Siddeley "Tiger" engine is a twelve-cylinder 60 degree Vee type of 160 mm. (6.3 in.) bore, 180 mm. (7.09 in.) stroke, and 2652.12 cu. in. total displacement. This engine is rated 600 h.p. at 1600 r.p.m., the first tests showing an output of 685 h.p. at 1640 r.p.m. The propeller speed is reduced by spur gearing at a ratio of .559. The compression ratio is 5.2; and the total dry weight is said to be 1350 lbs., or 2.25 lbs. per rated h.p. The overall dimensions are as follows: length 81.34 in., width 33.46 in., and height 39.57 in.

The cylinders are constructed separately, the cylinder head with the inlet and exhaust ports and the water jacket being an aluminum casting. Steel liners that are open at both ends screw into the head for a short distance and the water jacket joint at the lower end is made by a round rubber ring pressed against the steel liner by an annular aluminum nut. The bronze valve seats are expanded into place.

Fig. 430. Propeller End of Siddeley "Tiger."

There are two inlet and two exhaust valves in the cylinder head, inclined to the vertical axis. Each pair is actuated by a rocker arm from a central overhead camshaft which can be moved endwise to provide a half compression gear for starting. The valves are of the tulip design and employ volute springs, the clear diameter of all valves being 48 mm. (1.89 in.). The valve mechanism is enclosed by a housing which extends over six cylinders and is oil tight.

Lubrication is of the dry-sump pressure-feed type. There are two scavenge gear pumps, and one pressure pump which maintains from 25 to 40 lbs. per sq. in. oil pressure to the main bearings. Dual ignition is supplied by two twelve-cylinder magnetos, and starting is effected by an electric starter or compressed air. The centrifugal water pump is driven through a small plate clutch. The crankshaft is a six-throw seven-bearing type, and the connecting rods are of the forked design.

SIEMENS-HALSKE

The Siemens-Halske engines are of the air-cooled differential rotary type. The advantage of this type over the conventional rotary with fixed crankshaft is the lower speed of rotation which is obtained with relatively high piston velocities and results in a reduction in the power absorbed by air resistance, the unpleasant gyroscopic moment, and an increase in propeller efficiency. The 160-h.p. engine was used by the Germans in Siemens-Schuckert airplanes near the end of the war.

110-h.p. A nine-cylinder Siemens model of 114 mm. (4.48 in.) bore, 130 mm. (5.12 in.) stroke, and 726.39 cu. in. total displacement, gives from 110 to 115 h.p. at 900 r.p.m. of the propeller. The propeller is attached to the crankshaft and the cylinders turn at 900 r.p.m. in the opposite direction. The compression ratio is 3.96, and the fuel and oil consumption .581 and .077 lbs. per h.p-hr., respectively. The engine is said to weigh 309 lbs.

The steel cylinders have integral cooling fins, and exhaust valves seating co-axially in the heads that are operated by means of push rods and rockers. The inlet valves in the pistons are opened mechanically by cams on the connecting rods.

A bevel gear on the crankshaft and a similar gear attached to the crankcase that mesh with pinions in the stationary transmission housing effect the reverse direction of rotation of the cylinders and crankshaft.

The two sections of the single-throw crankshaft are joined by a taper at the crankpin. Mounted in large radial ball bearings are the disc sections which serve as crank-cheeks and have counter-weights attached thereto. The connecting rods are of the articulated type, and the pistons are fitted with two sets of double rings above the wrist pin. In front are two magnetos mounted cross-wise on brackets attached to the stationary transmission housing, and below the housing is a two-pistoned oil pump. The approximate overall diameter is 38 in. and the length 36.6 in.

Fig. 431. Longitudinal Section of Siemens-Halske Eleven-Cylinder Rotary Engine.

160-h.p. The eleven-cylinder 160-h.p. model has a maximum output of 240 h.p. As in the nine-cylinder type, both cylinders and crankshaft normally turn in opposite directions

at 900 r.p.m. This engine has a 124 mm. (4.88 in.) bore, 140 mm. (5.51 in.) stroke, and a total displacement of 1430.77 cu. in. The compression ratio is 5.1, and the consumption of fuel and oil .62 and .165 lbs. per h.p-hr., respectively. The weight is reported to be 428 lbs., or 2.67 lbs. per normal rated h.p.

Unlike the form of construction used in the 110-h.p. model, the propeller is carried on an extension of the crankcase. The stationary transmission housing, which also supports the engine, is now located to the rear. The ball bearings supporting the crankshaft are smaller in diameter, and are placed adjacent to the crank-cheeks.

The single-throw crankshaft is of built up construction, and the connecting rods are of the articulated type with "H" sections. Both inlet and exhaust valves are situated vertically in the cylinder head and operated by push rods and rockers. The cylinder head is nearly flat and has vertical fins running parallel across the top in the direction of rotation in addition to the horizontal circumferential fins upon the barrel. The aluminum pistons have concave heads with ribs underneath, and are fitted with four top rings.

SIMMS

The Simms was a six-cylinder water-cooled Vee type engine rated 51 h.p. at 1000 r.p.m. The bore and stroke were 110 mm. (4.33 in.), and the total displacement 382.56 cu. in. The weight was stated to be 220 lbs., or 4.31 lbs. per rated h.p.

SIZAIRE

The water-cooled eight-cylinder 90 degree Vee type Sizaire engine, which was under development in France during the war, was estimated to develop 350 h.p. at 2000 r.p.m. Reduction gears gave the propeller a normal speed of 1230 r.p.m., the propeller shaft being made hollow so that a 37 mm. gun mounted in the Vee could be fired through it. The cylinder bore was 130 mm. (5.12 in.), the stroke 170 mm. (6.73 in.), and the total displacement 1107.68 cu. in. The compression ratio was 5.6 to 1, and the weight was said to be 550 lbs., or 1.57 lbs. per estimated h.p.

The cylinders with water jackets were cast in blocks of four from aluminum. The detachable cylinder heads were

Fig. 432. Tranverse Section of Sizaire Engine.

integral with the cam housing. Each poppet inlet valve was operated directly by a cam, while the exhaust valve was a reciprocating sleeve whose motion was imparted by two small cranks on the overhead camshaft. There were also auxiliary exhaust ports formed near the bottom of the cylinder.

Fig. 433. End View of Sizaire Engine.

The four-throw crankshaft was supported in five roller bearings. Forked type connecting rods with tubular sections employed roller bearings at the crankpin end. The aluminum pistons had unusually long skirts, and a special duplex Zenith carburetor was mounted in the Vee. A gear pump circulated the oil; the oil passing through the hollow main bearing bolts to the main bearings, thence through copper pipes in the crankshaft to the crankpin bearings. The cooling water was circulated by a centrifugal pump with two outlets, and dual ignition was furnished by two eight-cylinder magnetos.

A water-cooled twelve-cylinder 60 degree Vee type Sizaire experimental design was rated at 600 h.p. The bore was 142 mm. (5.59 in.), the stroke 175 mm. (6.89 in.), and the total displacement 2029.08 cu. in. The weight was estimated to be 725 lbs.

SMALLE

The Smalle engine was used in a Farman type airplane entered by Campbell in the Los Angeles meet of January, 1911. This was a three-cylinder water-cooled engine, rated at 30 h.p.

SMITH

The Smith radial air-cooled engines were designed and built by Mr. John W. Smith of the Static Engine Company of Philadelphia, Pa. As a means of reducing weight through the omission of large counter-balances, ten cylinders were evenly disposed in a single plane about a two-throw crankshaft. Five slipper type connecting rods with "H" sections operated upon each crankpin. Since the plane of the cylinders was midway between the crankpin centers, the axes of the rods in each set were inclined to the plane of rotation.

The steel cylinders had integral cooling flanges, and concentric type valves were fitted co-axially in the head and operated by two push rods and rockers. A hole in the cylinder wall near the end of the stroke served as an auxiliary exhaust port. The engine was throttled by controlling the closing of the inlet valve in relation to piston position.

The principal feature of the Smith engine was the induction system, which consisted of a rotor with blades turning at crankshaft speed in a crankcase compartment connected by

pipes to all ten cylinders. The pipes extended in the compartment for a short distance so that fuel in liquid form could not drain into the lower cylinders. The action of the rotor was to break up the heavy particles and induce an even distribution of the mixture.

The smaller experimental Smith engine had a 4.53125 in. bore, 6.25 in. stroke, and a total displacement of 1007.87 cu. in. The engine developed 145 h.p. at 1500 r.p.m., and weighed complete with mounting 487 lbs., or 3.36 lbs. per h.p. The fuel consumption was .7 lbs. per h.p-hr.

The trunk type cast-iron pistons were fitted with two top rings. The clear diameter of the inlet valve was 1.75 in., and the outside diameter of the exhaust valve in which it seated was 2.5 in. The theoretical compression ratio, or that based on the volume swept, was 4.57 to 1. The lubricating system carrier a pressure of approximately 2.5 lbs.

Fig. 434. The Smith Air-cooled Radial Engine.

A larger experimental ten-cylinder Smith engine of 5.5 in. bore, 6.5 in. stroke, and 1543.7 cu. in. total displacement was built, but had very little running. This engine was intended to develop 300 h.p. at 1600 r.p.m.

Fig. 435. An Experimental 300-h.p. Smith Radial Engine.

SNADECKI

The Snadecki engine was a water-cooled eight-cylinder Vee type of 5.625 in. bore, 5.5 in. stroke, and 1093.4 cu. in. total displacement. It was designed by Mr. W. J. Snadecki and built by the Bridgeport Motor Company at Bridgeport, Connecticut. The engine developed approximately 280 h.p. at 1600 r.p.m, and was said to weigh 860 lbs., or 3.07 lbs. per h.p. The fuel consumption was reported to be 101 lbs. per hr., and the oil consumption 28 lbs. per hr.

Separate cylinders with heads containing cored water passages, were cast from grey iron and fitted around the

barrel with copper water jackets. Two exhaust valves and one inlet valve, standing vertically in the cylinder head, were operated through push rods and rockers by a central camshaft which was mounted on four ball bearings in the Vee and carried a separate cam for each valve.

The crankshaft had four throws and was supported in three ball bearings. Opposite cylinders in the Vee were staggered, hence the use of side-by-side connecting rods was permitted. The pistons were cast from iron and fitted with four eccentric rings.

Forced lubrication was provided by a gear pump, and the cooling water, whcih was circulated by a rotary pump, entered the cylinders at points just outside the exhaust valves. Dual ignition was furnished by two high-tension single-spark mag-

Fig. 436. End View of Snadecki Engine.

Fig. 437. Side View of Snadecki Engine.

netos, and the mixture was supplied by two Schebler carburetors. The overall dimensions of the engine were as follows: length 53.5 in., width 37.5 in., and height 39.625 in.

S. P. A.

The Societa Piemontese Automobili of Turin, Italy, began building airplane engines in 1908. The first engine was a 25-h.p. two-cylinder opposed type operating two propellers. Another air-cooled opposed type that developed 90 h.p. was constructed with eight cylinders, and there was also an eight-cylinder engine of the water-cooled Vee type. In 1915 the company built a ten-cylinder radial design.

In 1916 the plant was enlarged for manufacturing the S. P. A. 6-A type. This engine has also been built by Ansaldo San Giorgio, Breda, Talomona, and the Industrie Mecchaniche e Ferroviarie of Arezzo. The 6-A engine was built in three types, the normal, semi super-compressed, and the super-compressed.

Type 6-A Normal. The S. P. A. 6-A engine is a six-cylinder water-cooled vertical type of 135 mm. (5.31 in.) bore, 170 mm. (6.69 in.) stroke, and a total displacement of 888.9 cu. in. This engine is rated 150 h.p. at 1600 r.p.m. and weighs 562 lbs., or 3.74 lbs. per rated h.p.

The fuel consumption is said to be .473 lbs. per h.p-hr., and the oil consumption .033 lbs. per h.p-hr. The engine is

Fig. 438. Side View of the S. P. A. Type 6-A Engine.

either fitted with two single Zenith carburetors or one duplex Zenith carburetor type 55-DC. Lubrication is of the dry-sump pressure-feed type with a gear pump circulating the oil. Dual ignition is supplied by two H-2 or EM-6 Marelli magnetos, and the water is circulated by a centrifugal pump having double inlets.

The steel cylinders are arranged in pairs with mounting flanges welded together and encased by a common welded-on water jacket of three parts. The camshaft is situated overhead and driven by bevel gears from a vertical drive shaft. Single inlet and exhaust valves, located in the cylinder head and inclined to the vertical axis, each have a clear diameter of 2.1875 in., a lift of .46875 in., and 45 degree seats. The valve timing is as follows: the inlet opens 8 degrees late and closes 50 degrees late; the exhaust opens 62 degrees early and closes 14 degrees late.

The six-throw crankshaft is supported in four plain bearings, and the connecting rods have "H" sections and four-bolt caps. Aluminum pistons of the modified hour-glass type, are ribbed underneath the head and fitted with two upper rings and one lower oil scraper ring.

The super-compressed S. P. A. engine of the 6-A type is rated at 200 h.p., but is said to develop 235 h.p. at 1700 r.p.m.

and 240 h.p. at 1750 r.p.m. This engine is identical with the normal 6-A model except for a 2 mm. increase in cylinder bore, higher compression, and the use of connecting rods having tubular sections.

Fig. 439. End View of the S. P. A. Type 6-A Engine.

Type 6-2-A. An S. P. A. six-cylinder vertical water-cooled engine corresponding in design to the 6-A type, is rated at 250 h.p. The engine is said to develop 270 h.p. at 1700 r.p.m. and 310 h.p. at 1850 r.p.m. The bore is 140 mm. (5.51 in.), the stroke 180 mm. (7.09 in.), and the total displacement 1014.36 cu. in. The weight is reported to be 595 lbs., or 2.38 lbs. per rated h.p.

Type 1-A. A sixteen-cylinder 45 degree Vee type water-cooled engine, of the same bore and stroke as the 6-A Type, is rated 500 h.p. at 1500 r.p.m. The compression ratio is 5 to 1. and the total displacement 2370.4 cu. in. The cylinders and pistons are practically the same as used in the 6-A engine. The crankshaft has eight throws; two cranks, 180 degrees apart, being placed between each bearing. The connecting rods are of the articulated type, the master rods employing four-bolt caps. The engine is fitted with four carburetors, and the weight is said to be 1276 lbs., or 2.55 lbs. per rated h.p.

Type 2-A. An eight-cylinder vertical water-cooled engine, using the same cylinders as the super-compressed 6-A type, is rated 300 h.p. at 1600 r.p.m. The bore is 137 mm.

(5.39 in.), the stroke 170 mm. (6.69 in.), and the total displacement 1221.2 cu. in. The compression ratio is 5.3 to 1.

SPYKER

The Trompenburg-Spyker Works, Amsterdam, Holland, build a nine-cylinder air-cooled rotary engine of the Clerget type. The bore is 120 mm. (4.72 in.), the stroke 160 mm. (6.3 in.), and the total displacement 992.07 cu. in. This engine develops normally 135 h.p. from 1000 to 1200 r.p.m., and weighs 304 lbs., or 2.25 lbs. per rated h.p.

The cylinders with integral cooling fins are constructed from steel and fitted with a single inlet and exhaust valve. The connecting rods have tubular sections, and the pistons are made from aluminum. Dual ignition is supplied by magnetos.

Fig. 440. The Spyker Rotary Engine.

STAHL

The Stahl Motoren Gesellschaft in Germany have built four-cylinder vertical water-cooled engines in 50, 75, and 100-h.p. sizes. The cylinders were constructed in pairs from steel with a common welded-on water jacket.

Fig. 441. The Stahl 50-h.p. Engine.

STAHLHERZ

The Stahlherz air-cooled rotary engines, manufactured by Otto Schwade and Company of Erfurt, Germany, were copied from the Gnome. One of the features of interest was the arrangement for quickly detaching the cylinders. Inlet valves of the tangential type, operated exactly as the ordinary spring shut valve.

The smaller Stahlherz engine was a seven-cylinder type rated at 80 h.p. The bore was 124 mm. (4.88 in.), the stroke 140 mm. (5.51 in.), and the total displacement 722.75 cu. in. A double form, with fourteen cylinders and a total displacement of 1445.5 cu. in., was rated at 160 h.p.

Nine, eighteen, and thirty-six cylinder types were built with a 124 mm. (4.88 in.) bore and a 150 mm. (5.91 in.) stroke. The respective displacements in cubic inches were 993.18, 1986.36, and 3972.72, the corresponding rated output of each engine being estimated at 100, 200 and 400 h.p.

STATAX

The Statax Engine Co., Ltd., of London, during 1914 produced air-cooled rotary engines in which the axes of the cylinders were arranged parallel to the axis of rotation. Steel cylinders, fitted with a number of circular aluminum cooling

flanges, were held between the crankcase and the valve operating gear housing. This assembly was mounted upon ball bearings, which were supported on a stationary hollow shaft attached to the supporting frame.

The ring, to which the connecting rods were attached by universal joints, was mounted with ball bearings, capable of taking both radial and thrust loads, upon a disk secured to the shaft at an angle with the axis. The outer rim of this ring was made to move within curved guides formed upon or rigidly attached to the walls of the crank chamber; hence, while the cylinders and casing were rotating about the central shaft, the inclined ring moved with them and the outer rim oscillated in a longitudinal plane containing the axis of rotation.

Fig. 442. The Statax Five-Cylinder Rotary Engine.

The valve gear was located at the propeller end of the engine, the exhaust valves being operated by push rods and rockers and the inlet valves directly by cams. The inlet valves were provided with counter-weights to balance their centrifugal force, while the closing of the exhaust valves was benefited thereby. The cams were supported upon the central shaft by ball bearings and driven by planetary gearing. The

central stationary shaft served as a conduit for the oil pipes, and as an induction pipe for the gas mixture. Pressure lubrication was provided by a special three-throw pump, and Bosch magnetos furnished the ignition.

The smaller Statax engine had three cylinders and was rated 10 h.p. at 1400 r.p.m. The bore was 58 mm. (2.28 in.), the stroke 60 mm. (2.36 in.), and the total displacement 28.91 cu. in. The weight was stated to be 60 lbs., or 6 lbs. per rated h.p.

A five-cylinder engine of 100 mm. (3.94 in.) bore, 120 mm. (4.72 in.) stroke, and 287.75 cu. in. total displacement, was rated 40 h.p. at 1200 r.p.m This engine weighed 200 lbs., or 5 lbs. per rated h.p. A seven-cylinder 80-h.p. model and a ten-cylinder 100-h.p. model have also been constructed.

STOEWER

The Stoewer Automobile Works of Germany built six-cylinder vertical water-cooled engines of their own design, which were rated at 125, 150, and 180 h.p. respectively.

STURTEVANT

The B. F. Sturtevant Co., of Hyde Park, Boston, Massachusetts, began constructing airplane engines in 1911. The Sturtevant Models have been limited entirely to water-cooled vertical and Vee types.

Model D-4. The Sturtevant Model D-4 engine was a four-cylinder vertical type of 4.5 in. bore and stroke, and a total displacement of 286.28 cu. in. This engine developed 48 h.p. at 1300 r.p.m. and 55 h.p. at 1700 r.p.m., the dry weight including equipment being 220 lbs., and with water and oil 270 lbs. The fuel consumption was said to be .57 lbs. per h.p-hr., and the oil consumption .058 lbs. per h.p-hr.

Cylinders of the "L" head type and with integral water jackets were cast separately from semi-steel. The crankshaft was supported in five plain bearings, and the connecting rods had "H" sections. The pistons were made from cast iron and fitted with three rings. Mea magnetos furnished the ignition, and a Zenith carburetor the mixture. An oil pressure of 20 lbs. was maintained by a gear pump. The overall

Fig. 443. The Sturtevant Model D-4 Engine.

dimensions were as follows: length 39.5 in., width 19.875 in., and height 23.625 in.

Fig. 444. The Sturtevant Model D-6 Engine.

Model D-6. A six-cylinder vertical engine, identical in cylinder dimensions and with the same form of construction as the Model D-4 engine, had a total displacement of 429.42 cu. in., and was rated 73 h.p. at 1300 r.p.m. and 86 h.p. at 1700 r.p.m. The dry weight, including equipment, was said to be 320 lbs., and with water and oil 400 lbs. The overall dimensions were as follows: length 51.625 in., width 19.875 in., and height 2

Fig. 445. The Sturtevant Model E-4 Engine.

Model E-4. The Sturtevant Model E-4 four-cylinder engine had a 4.5 in. bore, 6 in. stroke, and a total displacement of 381.7 cu. in. This engine was rated 100 h.p. at 1800 r.p.m. The propeller was geared down to half engine speed by spur reduction gears, the propeller shaft being mounted on two ball bearings. The total dry weight including the flywheel was said to be 420 lbs.

The fuel consumption was reported to be .52 lbs. per h.p-hr., and the oil consumption .05 lbs. per h.p-hr. A Zenith carburetor bolted to the lower-half crankcase received air through an oil cooler. Either a fuel or an air pump was supplied with the engine. An oil pressure of approximately 50 lbs. was maintained by a rotary pump, the oil being carried in a sump which contained the oil cooler.

The cylinders were of the "T" head type, and were cast in one block with jackets integral from semi-steel. There were

four valves per cylinder operated directly through tappets from a camshaft on each side of the crankcase. The crankshaft had five plain bearings, manganese bronze bearing caps being held in place by the long through bolts which also held down the cylinders. The connecting rods had "H" sections, and the pistons were made from cast iron and fitted with three rings. A Bosch magneto furnished the ignition.

Model 5. The Sturtevant Model 5 engine was an eight-cylinder water-cooled 90 degree Vee type of 4 in. bore, 5.5 in. stroke, and 552.88 cu. in. total displacement. This engine was normally rated 140 h.p. at 2000 r.p.m., and was fitted with a gear reduction which gave the propeller a normal speed of 1200 r.p.m. The total dry weight was reported to be 580 lbs., or 4.14 lbs. per rated h.p. The fuel consumption was said to be .51 lbs. per h.p-hr., and the oil consumption .032 lbs. per h.p-hr.

Cylinders of "L" head type were cast in pairs with water jackets integral from semi-steel. The camshaft was situated in the Vee and operated, through tappets, single inlet and exhaust valves in each cylinder. The crankshaft had three plain bearings, and the connecting rods were arranged side by side on the crankpins. The connecting rods had "H" sections, and the pistons were of semi-steel.

Model 5-A. The Sturtevant 5-A engine was a modified Model 5 with no major changes in dimensions. This engine was also normally rated 140 h.p. at 2000 r.p.m., and was arranged for either direct propeller drive or reduction gears having a ratio of .6. The dry weight was reported to be 514 lbs., and the water content 36 lbs. The approximate overall dimensions were as follows: length 50 in., width 34 in., and height 35 in. Duplex Zenith carburetors furnished the mixture, and a gear pump pressure lubrication.

The cylinders were cast in pairs from aluminum and fitted with steel liners. The detachable cylinder heads were also cast in pairs of the same material. The camshaft was situated in the Vee and operated, through push rods and rockers, single inlet and exhaust valves located vertically in each cylinder head. The valve timing was as follows: the inlet opened

Fig. 446. End View of Sturtevant Model 5A-4½ Engine.

15 degrees early and closed 45 degrees late; the exhaust opened 45 degrees early and closed 10 degrees late.

The crankshaft was a four-throw three-bearing type, supported by separate bearing caps. The connecting rods had "H" sections and were arranged side by side upon the crankpins. The aluminum alloy pistons were deeply ribbed and fitted with two rings. The cooling water was circulated by a centrifugal pump, and dual ignition was supplied by either Dixie or Bosch magnetos.

Model 5A-4½. An eight-cylinder 90 degree Vee type water-cooled engine, closely resembling the 5-A Model, had a .5 in. larger bore and therefore a total displacement of 539.76 cu. in. This engine was rated 210 h.p. at 2250 r.p.m., and was capable of developing as maximum 240 h.p. The propeller was driven through plain type spur reduction gears at a normal speed of 1350 r.p.m. The dry weight was reported to be 480 lbs., and the water contained in the engine weighed approximately 35 lbs. The fuel consumption was said to be .55 lbs. per h.p-hr., and the oil consumption .038 lbs. per h.p-hr. Duplex Zenith carburetors and two eight-cylinder Dixie magnetos were fitted.

Fig. 447. Sturtevant Model 5A-4½ Engine.

Model 7. The Sturtevant Model 7 engine was a twelve-cylinder 60 degree Vee type, rated at 300 h.p. This engine followed the same general form of construction as the Model 5A-4½.

Fig. 448. Sturtevant Model 5A-4½ with Overhead Carburetor Equipment.

SUNBEAM

The Sunbeam Motor Car Co., Ltd., of Wolverhampton, England, originally began as John Marston and Sons, Ltd. This firm was organized about 1899 for manufacturing bicycles, the high quality of their product gaining for them an international reputation. Later the firm began to produce motor cars, Mr. Louis Coatalen, the Chief Engineer joining the Sunbeam Company in 1909. Attention was turned to airplane engines in 1912 after the Sunbeam racing cars had won the Coupé des Voiturettes in France.

The first Sunbeam airplane engines, that were envolved from the successful racing car engine designs, had water-cooled cylinders of the side-valve L-head type. The eight-cylinder 90 degree Vee design had a 90 mm. (3.54 in.) bore, 150 mm. (5.91 in.) stroke, and a total displacement of 465 cu. in. This engine was rated 150 h.p. at 2000 r.p.m., the propeller being driven off the camshaft at half engine speed. The fuel consumption was said to be .49 lbs per h.p-hr., and the oil consumption .032 lbs. per h.p-hr. The weight was reported to be 480 lbs.

The cylinders were cast en bloc from cast iron in groups of four, and had water jackets of copper, electrolytically deposited. The pistons were machined from the solid, the wrist pin being supported from the head of the piston. Opposite rows of cylinders were staggered, thus permitting the use of connecting rods side by side on each crank-pin. The crankshaft was carried in five plain bearings, and the propeller shaft in ball bearings. Claudel-Hobson carburetors were attached to four-cylinder inlet manifolds on the outside. Lubrication was by pressure feed from a gear pump, and ignition was furnished by one magneto.

The same cylinder dimensions were used in a twelve-cylinder 60 degree Vee engine of much the same design. The cylinders were in four groups of three, one carburetor supplying each group; and two magnetos were mounted crosswise at the anti-propeller end. This engine was rated 225 h.p. at 2000 r.p.m., and was said to weigh 725 lbs. The propeller shaft was driven from the camshaft, as in the 150-h.p. model, at half speed.

A twelve-cylinder engine, used in seaplanes, of the same rated output is reported to have employed a .6 propeller reduction ratio. The bore was 90 mm. (3.54 in.), the stroke 160 mm. (6.3 in.), and the total displacement 744 cu. in. The weight was said to be 905 lbs.

During 1914 and 1915, a series of water-cooled geared engines were produced with 90 mm. (3.54 in.) bore and 160 mm. (6.3 in.) stroke. The six-cylinder vertical type, of 372 cu. in. total displacement, was rated 170 h.p. at 2000 r.p.m. The propeller gear reduction ratio was .6. The cylinders were cast in blocks of three, and were supplied with four valves operated by separate overhead inlet and exhaust camshafts.

The twelve-cylinder 60 degree Vee type, of similar design, was rated 350 h.p. at 2000 r.p.m. This engine had a total displacement of 744 cu. in., and was said to weigh 1000 lbs. The propeller was driven at half engine speed.

An eighteen-cylinder W type, formed in three rows of six with the same cylinders, had a total displacement of 1116 cu. in. and was rated at 475 h.p.

Fig. 449. Propeller End of Sunbeam Eight-Cylinder Engine.

Fig. 450. Side View of Sunbeam Eight-Cylinder Engine.

In 1916, an eight-cylinder water-cooled Vee type was produced with a bore of 95 mm. (3.74 in.), a stroke of 125 mm. (5.31 in.), and 465.76 cu. in. total displacement. This engine was rated at 150 h.p. and reported to weigh 554 lbs.

Among the 1916-17 Sunbeam series was a six-cylinder vertical engine of 110 mm. (4.33 in.) bore, 160 mm. (6.3 in.) stroke, and 556.62 cu. in. total displacement. The propeller was geared to turn at 1000 r.p.m. The normal rated output was 160 h.p., and it was claimed that 170 h.p. was actually developed. The weight was reported to be 578 lbs., or 3.61 lbs. per rated h.p. The overall dimensions were as follows: length 56.29 in., width 19.09 in., and height 38.58.

A twelve-cylinder engine, of the same cylinder dimensions and therefore having a total displacement of 1113.24 cu. in., was rated at 320 h.p. and reported to have developed 350 h.p.

Fig. 451. Sunbeam 160-h.p. Engine.

Fig. 452. Side View of Sunbeam 160-h.p. Engine.

This engine was said to weigh 1040 lbs. The overall dimensions were as follows: length 61.8 in., width 37.8 in., and height 38.89 in.

Fig. 453. End View of Sunbeam 350-h.p. Engine.

Fig. 454. Side View of Sunbeam 350-h.p. Engine.

In this same series was also an eighteen-cylinder W type, of 1669.86 cu. in. total displacement, which was nominally rated at 450 h.p. and said to actually develop 475 h.p. The normal propeller speed was 900 r.p.m. The design followed the six and twelve-cylinder engines with additional parts in proportion to the increased number of cylinders. The weight was reported to be 1430 lbs., or 3.17 lbs. per rated h.p. The overall dimensions were as follows: length 63 in., width 46.5 in., and height 44.5 in.

Fig. 455. Side View oï Sunbeam Eighteen-Cylinder Engine.

Fig. 456. End View of Sunbeam Eighteen-Cylinder Engine.

"Afridi." The "Afridi" was a twelve-cylinder 60 degree Vee type engine, built during 1916 and 1917. It was nominally rated at 200 h.p. and said to actually develop 225 h.p. The bore was 92 mm. (3.62 in.) the stroke 135 mm. (5.31 in.), and the total displacement 659.83 cu. in. The normal speed of the propeller was 1050 r p.m. This engine was said to weigh 745 lbs., and measure overall as follows: length 55.9 in., width 33.5 in., and height 33.9 in.

"Dyak." The "Dyak" was a water-cooled six-cylinder vertical direct drive engine of 120 mm. (4.72 in.) bore, 130 mm. (5.12 in.) stroke, and 538.26 cu. in. total displacement. It delivered 100 h.p. at 1200 r.p.m., and weighed dry 399 lbs., and with water 439 lbs. The cylinders were cast en bloc, and two valves in each of the cylinder heads were operated by an overhead camshaft. The crankshaft was supported in seven bearings, and the connecting rods had "H" sections. The pistons were made from aluminum. Claudel-Hobson B. Z. S. 38 type carburetors furnished the mixture, and two M. L. six-cylinder magnetos dual ignition.

"Arab." The Sunbeam "Arab" engines had a 120 mm. (4.72 in.) bore, 130 mm. (5.12 in.) stroke, and 717.65 cu. in. total displacement. The geared engine with a .6 propeller

Fig. 457. End View and Transverse Section of Sunbeam "Arab" Engine.

ratio was known as the "Arab I," and the direct drive engine as the "Arab II."

These engines were eight-cylinder 90 degree Vee types having cylinders cast in two blocks of four each from aluminum. The rated output at 1600 r.p.m. was 200 h.p., and at 2000 r.p.m. it was 240 h.p. The dry weight of the "Arab I" engine was said to be 530 lbs., and the "Arab II" 517 lbs.

The cylinders were fitted with pressed in steel liners and screwed in valve seat inserts. There were two exhaust valves and one inlet valve in each cylinder operated by a camshaft situated directly over the inlet valves. The aluminum pistons were fitted with four rings, the lower one serving as an oil scraper. The connecting rods were of the articulated type

Fig. 458. Longitudinal Section of Sunbeam "Arab I."

with "H" sections, the stroke in the linked rod cylinder being 141 mm. The overall dimensions were as follows: width 31.9 in., height 35.5 in., the length of the "Arab I" 43.5 in. and the "Arab II" 40.9 in.

Fig. 459. Sunbeam "Arab I" Engine.

The "Arab" engines were also built by the Austin Motor Co. Considerable trouble has been experienced with these designs and as a result they have been completely abandoned.

"Maori 4." The Sunbeam "Maori 4" is a twelve-cylinder Vee type, specially designed for airship use, having been fitted to the British Admiralty Airships R.33 and R.34. This engine is rated 275 h.p. at 2100 r.p.m., and has a reduction gear with a ratio of .5. The bore is 110 mm. (4.33 in.), the stroke 135 mm. (5.31 in.), and the total displacement 738.78 cu. in. The dry weight of the engine including flywheel is 920 lbs., or 3.34 lbs. per rated h.p.

The cylinder blocks are of cast iron. There are four overhead valves in each cylinder, actuated by two camshafts to each row. The camshafts are driven by a train of gears. The connecting rods are of the articulated type and have "H" sections. Four Claudel-Hobson carburetors are fitted outside the Vee, and ignition is by two twelve-cylinder magnetos. A governor is fitted so that when the engine speed reaches 2500 r.p.m., or when the oil pressure falls below 20 lbs. per sq. in., the ignition is automatically cut off.

"Cossack." The twelve-cylinder Sunbeam "Cossack," a larger airship engine design, is fitted to the British Admiralty Airships R.36, R.37, and R.39. This model has a 110 mm. (4.33 in.) bore, 160 mm. (6.3 in.) stroke, and 1122 cu. in. total displacement. It is rated 350 h.p. at 2000 r.p.m., and is said to weigh with flywheel 1200 lbs., or 3.42 lbs. per rated h.p. This engine includes all of the special features contained in the "Maori 4" model.

"Manitou." The Sunbeam "Manitou" engine is a water-cooled twelve-cylinder 60 degree Vee type of the same dimensions as the "Maori 4." It is rated, however, 300 h.p. at 2000 r.p.m., and weighs dry 845 lbs., or 2.81 lbs. per rated h.p. This engine is designed for aviation purposes of all kinds. The cylinder blocks are cast from aluminum and fitted with steel liners, otherwise the general form of construction is quite the same as other Sunbeam models. The propeller reduction gears have a ratio of .635.

"Amazon." A six-cylinder vertical water-cooled engine, known as the "Amazon," is rated at 200 h.p. The normal speed

of the crankshaft is 2000 r.p.m. and that of the propeller 1000 r.p.m. The bore is 122 mm. (4.8 in.), the stroke 160 mm. (6.3 in.), and the total displacement 684 cu. in. The weight is said to be 530 lbs., or 2.65 lbs. per rated h.p. The overall dimensions are as follows: length 56.29 in., width 19.09 in., and height 38.58 in.

"Matabele." The Sunbeam "Matabele" is a double form of "Amazon" engine, the total displacement being 1368 cu. in. It is rated 420 h.p. at 2000 r.p.m., the propeller having a normal speed of 1225 r.p.m. The dry weight is said to be 1000 lbs., or 2.38 lbs. per rated h.p. The cylinders are cast in blocks of three from aluminum, and the carburetors are located in the Vee.

Fig. 460. The Sunbeam "Sikh" 850-h.p. Engine.

"Sikh." The latest airship engines built by Sunbeam are the "Sikh" models, which are not only of larger dimensions, but have several features of construction not common to the earlier types. The large "Sikh" engine is rated 850 h.p. at 1400 r.p.m., the normal speed of the propeller being 920 r.p.m. The bore is 180 mm. (7.09 in.), the stroke 210 mm. (8.27 in.), and the total displacement 4033.2 cu. in. The dry weight is reported to be 1952 lbs., or 2.29 lbs. per rated h.p.

The cylinders are machined separately from steel forgings and fitted with welded on sheet-steel water jackets. There

are three vertical inlet valves and three vertical exhaust valves in the cylinder head operated by means of push rods and rockers. The pistons are of aluminum, and the connecting rods are of the forked design with "H" sections. The crankshaft is carried in eight plain bearings. There are two carburetors situated at each end of the engine, and ignition is by two twelve-cylinder magnetos.

Fig. 461. The Sunbeam "Semi-Sikh" 425-h.p. Engine.

"Semi-Sikh." A six-cylinder vertical direct drive engine, known as the "Semi-Sikh," is in reality one-half of the 850-h.p. model. This engine has a total displacement of 2016.6 cu. in., and is rated 425 h.p. at 1400 r.p.m.

SYLPHE

The Sylphe air-cooled rotary engine was built by the Bavarian Engine and Plane Company. It had five cylinders of 110 mm. (4.33 in.) bore, 130 mm. (5.12 in.) stroke, and 376.95 cu. in. total displacement, and was rated 35/40 h.p. at 1200 r.p.m.

The cylinders with cooling flanges were machined from a solid billet of chrome-nickel steel; the same material was also used in the construction of the crankshaft, connecting rods, valves, cams, and gears. The crankcase was made of a special high-grade bronze.

The mixture entered the crank compartment through the hollow crankshaft. The inlet valves were located in the piston and operated automatically, while the exhaust valves were controlled by cams. Lubrication was provided by a four-cylinder plunger pump.

Fig. 462. The Sylphe Rotary Engine.

THAMES

The Thames Ironworks, Shipbuilding and Engineering Co., Ltd., of Greenwich, S. E. London, England, produced a four-cylinder horizontally opposed water-cooled engine, rated at 30 h.p., about 1908. This engine was used in flight at Newcastle on Tyne about 1910.

Ball bearings were used for main and crank-pin bearings. The crankshaft was built up, the center disc being a spiral gear driving the camshaft. The camshaft was at right angles to the crank axis and operated horizontal valves.

THOMAS

The Thomas airplane engines were built by the Thomas Aeromotor Company, and the newer organization known as the Thomas-Morse Aircraft Corporation of Ithaca, N. Y. Their first engine, a four-cylinder vertical water-cooled type, rated at 120 h.p., was produced in 1912. Since that time the company has confined its efforts almost entirely to eight-cylinder water-cooled Vee types.

Model 8. The 135-h.p. model, which operated normally at 2000 r.p.m., was fitted with reduction gears giving the propeller a normal speed of 1200 r.p.m. This engine had a 4 in. bore, 5.5 in. stroke, and a total displacement of 552.88 cu. in.; and was said to weigh 600 lbs., or 4.44 lbs. per rated h.p.

Cylinders of the "L" head type were cast from grey iron in pairs with water jackets integral. The valves had a 2.125 in. clear diameter and a .4375 in. lift. Lubrication was of the pressure-feed type, and a 2 in. duplex Zenith carburetor furnished the mixture. Ignition was supplied by two four-spark magnetos. The four-throw crankshaft had three main bearings, and the connecting rods were arranged side by side on the crank-pin.

Fig. 463. Side View of the Thomas Model 88

Model 88. A more refined type, known as Model 88, which was placed on the market in 1916, was rated 150 h.p. at 2100 r.p m. The bore was 4.125 in., the stroke 5.5 in., and the total displacement 588 cu. in. The weight was said to be 525 lbs., or 3.5 lbs. per rated h.p.

The general arrangement of this engine was similar to the earlier model, the "L" head type cylinders being also cast in pairs with water jackets integral. Aluminum, however, was substituted for grey iron; the cylinder barrels were then fitted with steel liners, and the cylinder heads made detachable.

The consumption of fuel was said to be .6 lbs. per h.p-hr., and the consumption of oil .06 lbs. per h.p-hr. Duplex Zenith carburetors supplied the mixture, and a gear pump maintained an oil pressure of 50 lbs. per sq. in. at the bearings. Two Dixie magnetos supplied the ignition.

Model 890. The largest Thomas eight-cylinder water-cooled Vee type engine was rated 250 h.p. at 2200 r.p.m. The

Fig. 464. End View of the Thomas Model 88.

normal propeller speed was reduced by spur gearing to 1512 r.p.m. The bore was 4.8125 in., the stroke 6 in., and the total displacement 873.12 cu. in. The total weight was reported to be 590 lbs., or 2.36 lbs. per rated h.p.

The "L" head type cylinders were cast from aluminum in blocks of four with water jackets integral. The cylinder heads were made detachable, and the cylinder barrels were fitted with cast-iron liners. The inlet and exhaust valves each had a clear diameter of 2.8125 in.

The crankshaft was a four-throw three-bearing type, and the staggered cylinder arrangement permitted the connecting rods to be placed side by side upon the crank-pins. The white metal of the big end bearings was applied directly to the steel. The connecting rods had "H" sections; the aluminum pistons were ribbed underneath the head and fitted with two top rings and one lower oil scraper ring.

Fig. 465. Transverse Section and Rear End View of Tips Engine.

The mixture was supplied by a Stromberg duplex carburetor, and the oil pressure was maintained by a gear pump. The fuel consumption was said to be .54 lbs. per h.p-hr., and the oil consumption .04 lbs. per h.p-hr. Dual ignition was provided by two Dixie magnetos. For starting, either a hand starting magneto or a Christensen air starter could be applied.

TIPS

The Tips engine was a geared differential rotary type provided with both water and air-cooling. The normal speed of the crankshaft was 1800 r.p.m.; the propeller, through an arrangement of planetary and eccentric gears, revolved at 1080 r.p.m., while the main body turned at only 60 r.p.m. The slow rotation of the main body caused the water to circulate from the jackets through the nine tubular radiators built between the cylinders. This particular system eliminated all water hose connections.

Eighteen cylinders of 4.5 in. bore, 6 in. stroke, and 1717.67 cu. in. total displacement, were arranged in two rows of nine.

Fig. 466. Longitudinal Section of Tips Engine.

The maximum output was estimated at 480 h.p., and the weight (including the cooling system) was said to be 850 lbs., or 1.77 lbs. per rated h.p. The compression ratio was 5.25 to 1.

A decompression valve was provided in the main body. A tapered rotary sleeve valve, that was water-cooled internally, self-lubricated, and automatically self-adjusted, was driven by spirals from the main planetary gear mechanism. Each sleeve, which operated in a cast-iron housing, was lubricated with graphite and supplied a pair of cylinders for both inlet and exhaust.

The carburetor and oil pump had a common body made from an aluminum casting. Overflow oil, that had been forced through the crankshaft and bearings, was splashed regularly by the slow rotation of the main body. There were three double obturator rings per piston.

TOMONO

The Tomono was a six-cylinder vertical water-cooled engine, rated 90 h.p. at 1200 r.p.m. The bore was 4.5 in., the stroke 4.375 in., and the total displacement 417.48 cu. in. The weight was reported to be 397 lbs., or 4.41 lbs. per rated h.p.

The Tomono engine was designed and built by Tomono Naoji, to be entered in the engine trials held on June 22, 1917, by the Imperial Aviation Association of Japan. Although the engine was not finished in time, it was tested by the committee but no test results were reported.

TONE

The Tone Model 2V9 was rated 180 h.p. at 1800 r.p.m. The bore was 4.5 in. and the stroke 6.25 in. This engine was equipped with Zenith carburetors and Delco self-starter and ignition. The total weight was said to be 576 lbs., or 3.2 lbs. per rated h.p.

TOSI

Before the war, the Franco Tosi Works of Legnano, (Milan) Italy, constructed engines for various purposes. In order to increase the production of airplane engines for military uses, they undertook the building of the Isotta-Fraschini V4-B type. Some time later the Tosi Company built a design

Fig. 467. The Tosi 400-h.p. Engine.

of their own, and the results obtained were said to have been quite satisfactory. The Tosi engines bear some resemblance to the Isotta-Fraschini designs.

The Model V-12 Tosi engine was a water-cooled twelve-cylinder 60 degree Vee type, rated at 400 h.p. This engine is reported to have developed 440 h.p. at 1600 r.p.m. and 500 h.p. at 1700 r.p.m. The bore was 130 mm. (5.12 in.), the stroke 190 mm. (7.48 in.), and the total displacement 1846.68 cu. in. The compression ratio was 5.5 to 1.

The fuel consumption was said to be .478 lbs. per h.p-hr., and the oil consumption .026 lbs. per h.p-hr. Two duplex carburetors were situated in the Vee, pressure-feed lubrication was employed, and dual ignition was supplied by two twelve-cylinder magnetos.

The cylinders were made up in pairs and encased in sheet-steel water jackets held in place by screws. Single inlet and exhaust valves were operated through rockers by an overhead camshaft. The crankshaft was a six-throw four-bearing type, and the connecting rods were of forked variety with tubular sections. The aluminum pistons were fitted with four rings, the ring located below the wrist pin serving as an oil scraper.

The complete weight was reported to be 1212 lbs., or 3.03 lbs. per rated h.p. The approximate overall dimensions were as follows: length 57 in., width 34.8 in., and height 37 in.

TREBERT

The Trebert Engine Works constructed two types of airplane engines about 1912. The air-cooled rotary type, rated at 60 h.p., had six cylinders arranged with axes parallel to the central shaft. The bore was 3.75 in., the stroke 4.25 in., and the total displacement 281.64 cu. in. The propeller speed was reduced one-half by small bevel gears at the inner end of each shaft meshing with the large central gear.

The cylinders were of cast-iron construction and employed rotary type valves. A Panhard carburetor supplied the mixture, and Mea magnetos the ignition. The weight (completely equipped) was said to be 230 lbs., or 3.83 lbs. per rated h.p. The overall length was 22 in., and the outside diameter 15.5 in.

Fig. 468. The Trebert Six-Cylinder Barrel Rotary Type Engine

An eight-cylinder water-cooled Vee type engine of 4.875 in. bore, 5 in. stroke, and 746.6 cu. in. total displacement, was rated 100 h.p. at 1200 r.p.m. One of the outstanding features of this engine was the piston valve design. The "L" head cylinders with integral water jackets were made from cast iron. The crankshaft was supported in five bearings, and the articulated type connecting rods employed "H" sections. The pistons were made from cast iron and fitted with three rings.

Panhard carburetors supplied the mixture, and Mea magnetos the ignition. A splash system of lubrication was employed, the valves being lubricated by introducing oil into the fuel. The weight was said to be 350 lbs., or 3.5 lbs. per rated

h.p. The overall dimensions were as follows: length 48 in., width 26.5 in., and height 30 in.

Fig. 469. The Trebert Eight-Cylinder Engine.

TWOMBLY

The Twombly Motor Company built a seven-cylinder air-cooled rotary engine, during 1912, that was rated at 50 h.p. The bore was 4 in., the stroke 4.5 in., and the total displacement 395.85 cu. in. The cylinders were constructed of steel. The engine was equipped with Kingston carburetors and Bosch magnetos, and employed gravity-feed lubrication. The weight (completely equipped) was reported to be 112 lbs., or 2.24 lbs. per rated h.p. The overall length was 37 in., and the outside diameter 36 in.

UNION

The Union Gas Engine Company of Oakland, California, build a six-cylinder vertical water-cooled engine for use principally in lighter than air craft. The bore is 4.75 in., the stroke 6.5 in., and the total displacement 691.14 cu. in. The engine is rated 120 h.p. at 1350 r.p.m. and consumes .558 lbs. of fuel per h.p-hr. and .124 lbs. of oil per h.p-hr.

The individual cylinders are constructed with steel barrels, cast-iron heads, and copper water jackets which are pressed in place. The camshaft is situated overhead and operates both inlet and exhaust valves in each cylinder head

UNIVERSAL TEST ENGINE

In all strictness, a description of the Universal Test Engine is out of place, but is included because of its usefulness in airplane engine cylinder development. These test beds were designed and built at McCook Field, Dayton, Ohio,

during 1919; the four units now on hand permit two being in operation almost continuously at the Power Plant Laboratories.

The Universal Test Engine is designed to test any single air or water-cooled cylinder of conventional design having from 4 to 8 in. bore and 4 to 10 in. stroke. The engine is heavily constructed throughout for the sake of rigidity, and also to prevent serious damage in case of failure of the parts under test.

Means are provided for varying the compression ratio through a wide range. From one to four spark plugs may be used with either magneto or battery ignition; the adjustment of spark synchronization is easily accomplished, and the advance and retard mechanism is controlled by one lever.

The universal crankshaft is a patented feature which permits changing the length of the stroke. The shaft is made in three sections, the center section having a crank-pin inter-posing two discs which fit into eccentric recesses in the two large outer discs, with integral main journals, and are bolted and doweled thereto. The large discs afford a suitable surface for attaching counter-weights, and serve to supplement the action of the regular flywheel.

Two standard flywheels are sufficient for the range of cylinders and speeds employed. A standard connecting rod for each length of stroke in even inches is designed for use with cylinders of any diameter employing any compression ratio within the prescribed limits.

A camshaft is situated on each side of the cast-iron crankcase to operate push rod valve gears, and a hollow splined shaft will receive the splined end of a vertical shaft for driving an overhead camshaft, without any alterations when varying the stroke or compression ratio. The cams for either overhead or side camshafts are made separately and attached to the shafts by splines.

U. S. A. ENGINEERING DIVISION, AIR SERVICE

Model W-1. One of the important projects undertaken by the Engineering Division of the Army Air Service at McCook Field, Dayton, Ohio, during the year following the signing of the Armistice, was the design and development of

Fig. 474. The Model W-1 Engine.

a 750-h.p. water-cooled engine, known as the Model W-1. The results of the bench tests on the first engine, which was completed late in 1920, far surpassed expectations. The engine is now being more fully developed as a standard type for the Air Service.

The Model W-1 engine has eighteen cylinders arranged in three rows of six with the two outer rows at 40 degrees to

Fig. 475. End Views of Model W-1 Engine.

the vertical center row. The bore is 5.5 in., the stroke 6.5 in., and the total displacement 2778.66 cu. in. The normal compression ratio is 5.4. The engine is rated 700 h.p. at 1700 r.p.m. and 750 h.p. at 1800 r.p.m., but the preliminary tests have shown a much higher power output. The complete dry weight is approximately 1725 lbs.

The individual cylinders are of built-up steel construction, the cylinder barrel being screwed and welded into a

Fig. 476. Transverse Section through Cylinders and Center Main Bearing of Model W-1 Engine.

forged-steel cylinder head which has four forged-steel valve ports welded thereto. The water jackets are formed in two sections from sheet-steel and welded in place. The inlet and exhaust valves of 1 75 in. clear diameter, .375 in. lift, and 30 degree seats, are inclined at an angle of 15 degrees to the vertical cylinder axis, and are operated by a forked rocker from an overhead camshaft with a cam for each pair of valves. The single piece camshaft housing extends over the heads of each

Fig. 477. Transverse Section through Intermediate Main Bearing of Model W-1 Engine.

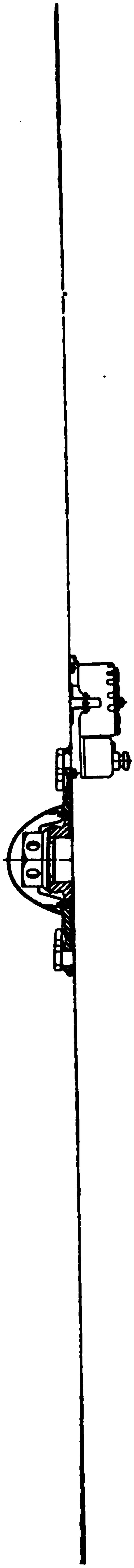
row of six cylinders and is held down to each cylinder by four studs. The camshafts are driven by vertical shafts and bevel gears at the rear end. Attached to the front end of each camshaft housing is an oil drain pipe which contains the camshaft oil pressure line. The valve timing is as follows: inlet opens 10 degrees late and closes 40 degrees late; the exhaust opens 50 degrees early and closes 10 degrees late.

The connecting rods are of the articulated type, the symmetrical master rods operating in the center row of cylinders. The lower ends of the linked rods are forked, and all three rods

Fig. 478. Section through Camshaft Driveshaft of Model W-1 Engine.

have "H" sections. The pistons are made from aluminum and fitted with four top rings, the lower of which acts as an oil scraper. The six-throw crankshaft is supported in eight plain bearings, one being just outside the deep-race annular ball bearing which carries the propeller thrust loads.

The mixture is supplied by six Stromberg carburetors located underneath the lower-half crankcase, and feeding into long steel induction pipes which pass through the crankcase



but are not rigidly attached thereto. Flanges at the upper ends join these pipes with the water-jacketed cast aluminum inlet manifolds which feed three cylinders each. The induction pipes have packing joints at the top and bottom and are exposed to the oil splash of the crank compartment. They are so arranged, adjacent the intermediate bearings, that the six inlet manifolds are identical, and at the two remaining positions, breather tubes are inserted. In order to carry out this symmetrical arrangement, the inlet and exhaust sides of the rear three cylinders of the center row are reversed in respect to those of the first three cylinders.

The crankcase is cast in three sections from aluminum. The outer wall of the upper-half crankcase is carried to the outside edge of the engine supports. The lower-half is shallow in section, and has the effect of individual bearing caps with the side walls tieing them together. Both upper and lower halves have double transverse walls and are doweled and held together by long through bolts. The oil pan is bolted to the lower-half crankcase and carries the oil and water pump bracket.

The water pump has two outlets, which pass inside the engine frame members on both sides, and are connected with similar water manifolds delivering to nine cylinders each. The gear pump delivers oil to a manifold which bolts underneath to the lower-half crankcase. The camshaft and accessory drives are contained in a gear case bolted over the three crankcase sections at the rear end. Provision is made for driving four eighteen-cylinder Splitdorf magnetos, each one firing one of the four plugs in each cylinder. A Bijur electric starter is mounted on the gear case and engages with the floating accessory drive gear. The oil and water pumps are driven by a horizontal shaft in the oil pan. At the rear end of this shaft is driven an electric generator, and at right angles and just below is a gear gasoline pump.

Model W-2. A larger water-cooled eighteen-cylinder W type of later design is being built experimentally. This engine bears very little resemblance to the W-1 design. The bore is 6.5 in., the stroke 7.5 in., and the total displacement 4479.66 cu. in. The engine is estimated to normally deliver 1000 h.p. at 1400 r.p.m., and weigh 2400 lbs.

VAN BLERCK

The Van Blerck Engine Company of Monroe, Michigan, constructed experimentally, two types of airplane engines during 1914 and 1915. The cylinders were separately machined from steel forgings and fitted with spun-copper water jackets; single inlet and exhaust valves, situated in the cylinder head, being operated by means of push rods and rockers. The crankcase was of steel construction, opposite cylinders in the Vee being staggered so as to permit the use of side by side connecting rods. The connecting rods had tubular sections, and the pistons were made from cast iron. Lubrication was of the pressure-feed type.

The eight-cylinder water-cooled Vee type of 4.5 in. bore, 5.5 in. stroke, and 699.76 cu. in. total displacement, was rated 135 h.p. at 1600 r.p.m. The weight was said to be 420 lbs., or 3.11 lbs. per rated h.p. The mixture was supplied by two carburetors, and the ignition by two four-spark magnetos.

A twelve-cylinder water-cooled Vee type, employing the same cylinders and having a total displacement of 1049.64 cu. in., was said to develop 185 h.p. at 1400 r.p.m. and 200 h.p. at 1600 r.p.m. The same general form of construction was employed throughout. The ignition was supplied by two twelve-cylinder magnetos, and the weight was claimed to be 600 lbs., or 3 lbs. per rated h.p. at 1600 r.p.m.

Fig. 480. Side View of Van Blerck Twelve-Cylinder Engine.

Fig. 481. End Views of Van Blerck Engine.

VAUXHALL

The Vauxhall was an experimental twelve-cylinder 60 degree Vee type water-cooled engine designed by L. H. Pomeroy and built by the Vauxhall Motors, Ltd., at Luton Beds, England, during the war. It was rated at 175 h.p., but is said to have developed 192 h.p. at 2000 r.p.m. The propeller speed was reduced by gearing to .4 that of the crankshaft. The bore was 90 mm. (3.54 in.), the stroke 120 mm. (4.72 in.), and the total displacement 557.52 cu. in.

The cylinders were of the built-up steel construction with welded-on sheet-metal water jackets. The mixture was furnished by four B & B carburetors, the lubrication by two plunger pumps, and the ignition by Dixie magnetos. The dry weight was reported to be 460 lbs., or 2.63 lbs. per rated h.p.; and the water content of the engine was 144 lbs. The overall dimensions were as follows: length 47.32 in., width 33.86 in., height 35.24 in.

VERDET

The Verdet was a seven-cylinder air-cooled rotary engine, rated 55 h.p. at 1100 r.p.m. The bore was 112 mm. (4.41 in.),

the stroke 140 mm. (5.51 in.), and the total displacement 589.12 cu. in. The weight was said to be 176 lbs., or 3.2 lbs. per rated h.p.

VIALE

Air-cooled radial engines were produced by Viale in France about 1910.

VIKING

A sixteen-cylinder air-cooled X type engine, known as the Viking, was announced during 1919 by the Detroit Manufacturers' Syndicate, Inc., of Detroit, Michigan. There were four rows of four cylinders each set at an angle of 90 degrees to each other. The Viking engine had a 3.25 in. bore, a 4 in. stroke, and a total displacement of 530.88 cu. in.; and was said to develop 140 h.p. at 1600 r.p.m.

The cylinders with integral cooling flanges were constructed individually from semi-steel, and attached to the

Fig. 482. The Sixteen-Cylinder Viking Engine.

aluminum crankcase by four flange bolts and four long binding bolts. The crankshaft was of built-up construction, annular ball bearings being used throughout. There were eight crank-throws, eleven main bearings, and sixteen connecting rod bearings since the connecting rods were arranged side by side on the crank-pin. A camshaft, situated in both upper and lower Vees, operated the inlet and exhaust valves in each cylinder head through push rods and rockers. Each valve had a clear opening of 1.4375 in. and a .3125 in. lift. The pistons were made from aluminum.

Lubrication was provided by spray from the upper hollow camshaft that was supplied with oil under pressure from a pump. Another pump was employed to scavenge the system, and the ignition was furnished by Dixie magnetos. The total weight of the engine (completely equipped) was reported to be 306 lbs., or 2.83 lbs. per rated h.p. The fuel consumed per hr. was said to be approximately 30 lbs. at 1400 r.p.m., and 36 lbs. at 1600 r.p.m.

VIVINUS

The Vivinus engines were built in France during 1910 and 1912. These engines were all four-cylinder vertical water-cooled types fitted with pressed-steel flywheels. The valves were located in the cylinder head and operated by means of push rods and rockers.

The smaller Vivinus engine, rated 32.5 h.p. at 1600 r.p.m., had a 106 mm. (4.17 in.) bore, 120 mm. (4.72 in.) stroke, and a total displacement of 257.84 cu. in.

Another model, which was rated 37.5 h.p. at 1600 r.p.m., had a 112 mm. (4.41 in.) bore, 130 mm. (5.12 in.) stroke, and a total displacement of 312.84 cu in. This engine was said to weigh 336 lbs., or 9 lbs. per rated h.p.

A Vivinus engine of 115 mm. (4.53 in.) bore, 130 mm. (5.12 in.) stroke, and 330.08 cu. in. total displacement, was rated 39 h.p. at 1800 r.p.m. and said to weigh 280 lbs., or 7.1 lbs. per rated h.p.

A later design, rated at 50 h.p., employed a geared propeller drive; the reduction gears were not enclosed by any

Fig. 483. The Vivinus Four-Cylinder 50-h.p. Engine.

housing. The 50-h.p. engine was said to weigh 300 lbs., or 6 lbs. per rated h.p.

V. N. V.

An experimental direct drive engine, known as the V. N. V., has been built by the Nagliati Company of Milan, Italy, with Hispano Suiza Model-34 cylinders of 120 mm. (4.72 in.) bore and 130 mm. (5.12 in.) stroke. Three four-cylinder blocks were arranged in the form of a Y, the total piston displacement being 1075.08 cu. in. This engine was rated 160 h.p. at 1100 r.p.m., and was said to weigh 595 lbs., or 3.71 lbs. per rated h.p.

This company has also experimented with a double four-cylinder vertical two-cycle engine of 120 mm. (4.72 in.) bore, 100 mm. (3.94 in.) stroke, and 551.44 cu. in. total displacement. Two crankshafts with opposite direction of rotation were geared to a single propeller shaft which turned at half engine speed. The engine was rated 250 h.p. at 2000 r.p.m., and was said to weigh 640 lbs., or 2.56 lbs. per rated h.p. The approximate overall dimensions were as follows: length 59 in., width 21.65 in., and height 39.37 in.

Fig. 484. The W. B. B. Two-Cycle Engine.

W. B. B.

A two-cycle four cylinder Vee type engine, known as the W. B. B., was constructed by C. Harold Wills of Detroit, for use in a special aerial torpedo, with capacity for 250 lbs. of explosive, that was being built by the Sperry Gyroscope Co. This engine was constructed mainly of aluminum, the air-cooled cylinders having thin steel liners pressed into place.

WEGER

The Weger six cylinder water cooled radial engine has been built experimentally by the Cleveland Engineering Laboratories Company. This engine operates on the two-stroke cycle, and has pumping cylinders to scavenge the exhaust and raise the initial pressure to about 8 lbs. above atmosphere at the beginning of the compression stroke. The working cylinders have a 4.25 in. bore, the pumping cylinders a 5.5 in. bore, and both a 5 in. stroke. These cylinders are arranged together in tandem and therefore operate about a two-throw crankshaft.

The engine is estimated to develop 400 h.p. and during tests has delivered an output of approximately 250 h.p. The dry weight is said to be 1100 lbs. Sleeve valves in the pumping cylinders are operated by a Scotch yoke and uncover ports communicating with the working cylinder at the proper interval during the cycle. Articulated type connecting rods are employed for both working and pumping cylinders.

WEINBERG

Among the engines designed and built by Mr. Fred Weinberg of Detroit, Mich., are the Albatross, Detroit Aero, and Michigan. His latest efforts in airplane engine construction is a 350-h.p. nine-cylinder air cooled radial of 5.875 in. bore and 6 in. stroke, that is being developed by the Engineering Division of the Air Service.

WELLS-ADAMS

The Wells-Adams water-cooled eight-cylinder Vee type engine was rated 135 h.p. at 1350 r.p.m. The bore was 4.5 in., the stroke 6 in., and the total displacement 763.39 cu. in. The weight was approximately 400 lbs., or 2.96 lbs. per rated h.p.

The individual cylinders were fitted with nickel plated spun brass water jackets. The water outlet, the valve rocker arm bracket, and the connection for the inlet manifold of each cylinder were cast integrally from aluminum. The valves were situated in the cylinder head and operated through push rods from a central camshaft in the Vee. The connecting rods had tubular sections, and dual ignition was furnished by Bosch magnetos.

Fig. 485. The Wells-Adams Engine.

WERNER

A four-cylinder water-cooled Werner engine, rated at 30 h.p., was used in a machine which J. J. Slavin entered in the Los Angeles meet of January, 1911.

Fig. 486. The 90/95-h.p. W. and P. Engine.

WERNER & PFLEIDERER

The German built Werner and Pfleiderer engines employed individual cylinders that were turned from solid billets of steel and fitted with seamless sheet-nickel water jackets. Each crankshaft had main bearings on either side of a crank throw, and was supported to the upper-half crankcase by caps, and through bolts that were also used to hold down the cylinders. The lower-half crankcase served only as an oil pan. Lubrication was by individual piston pumps, and dual ignition by Bosch magnetos.

Fig. 487. The Six-Cylinder W. and P. Engine.

Fig. 488. The 95-h.p. Inverted W. and P. Engine.

The 90/95-h.p. W. and P. engine was a four-cylinder vertical water-cooled type weighing 320 lbs. The bore was 130 mm. (5.12 in.), the stroke 150 mm. (5.91 in.), and the total displacement 486.36 cu. in.

A 95-h.p. four-cylinder inverted type of the same cylinder dimensions was also produced by Werner and Pfleiderer.

The six-cylinder water-cooled engine, rated at 140/150 h.p., was said to weigh 452 lbs. The bore was 130 mm. (5.12 in.), the stroke 160 mm. (6.3 in.), and the total displacement 777.66 cu. in.

The Werner and Pfleiderer eight-cylinder model was rated at 220 h.p. The bore was 130 mm. (5.12 in.), the stroke 180 mm. (7.09 in.), and the total displacement 1166.96 cu. in. This engine was reported to weigh 595 lbs., or 2.7 lbs. per rated h.p.

WESSEX

The Wessex was a six-cylinder vertical water-cooled engine, rated 130 h.p. at 2200 r.p.m. The propeller was driven through gears at one-half crankshaft speed. The bore was 105 mm. (4.13 in.), the stroke 150 mm. (5.91 in.), and the total displacement 475.02 cu. in.

WHERRY

The Wherry was an experimental air-cooled barrel rotary type engine, constructed in England during 1916.

Fig. 489. The Wherry Rotary Engine.

WHITE & POPPE

The White and Poppe was a British built eight-cylinder water-cooled Vee type engine, rated 130 h.p. at 1200 r.p.m. The bore was 120 mm. (4.72 in.), the stroke 160 mm. (6.3 in.), and the total displacement 881.84 cu. in.

Fig. 490. The Williams 125-h.p. Engine.

WILLIAMS

The Williams eight-cylinder water-cooled Vee type engine was rated at 125 h.p.

WISCONSIN

The Wisconsin Motor Manufacturing Company of Milwaukee, Wisconsin, in addition to their regular production of

Fig. 491. End View of Wisconsin 140-h.p. Engine.

automobile and truck engines, have also constructed racing car and airplane engines in small numbers.

The six-cylinder vertical water-cooled Wisconsin engine, rated 140 h.p. at 1400 r.p.m., was said to develop 140 h.p. at 1300 r.p.m. and 148 h.p. at 1400 r.p.m. The bore was 5 in., the stroke 6.5 in., and the total displacement 765.83 cu. in. The compression ratio was 4.55 to 1. The weight was said to be 600 lbs., and the water content of the engine 100 lbs.

Fig. 492. Inlet Side of Wisconsin 140-h.p. Engine.

The cylinders were cast in pairs from aluminum and fitted with hardened steel liners shrunk in and ground. Cast-iron valve seats were cast in place. The camshaft was situated overhead and driven by a vertical shaft and bevel gears, the camshaft housing being two aluminum castings joined along the horizontal. Single inlet and exhaust valves of 2.75 in. diameter and .5 in. lift were operated through rocker arms.

Fig. 493. Exhaust Side of Wisconsin 140-h.p. Engine.

The six-throw crankshaft was supported in four plain bearings. The aluminum pistons were ribbed under the head and fitted with two top rings. The mixture was supplied by one duplex Zenith carburetor, and dual ignition by two six-cylinder magnetos. Lubrication was of the pressure-feed type.

The twelve-cylinder engine, which was a double form of the 140-h.p. model, had a total displacement of 1531.65 cu. in. and was rated 250 h.p. at 1200 r.p.m. The design resembled the six-cylinder model except that the overhead camshafts were driven through a train of spur gears, and the connecting rods were of the articulated type. The total dry weight was reported to be 1000 lbs., or 4 lbs. per rated h.p.

Fig. 494. End View of Wisconsin Twelve.

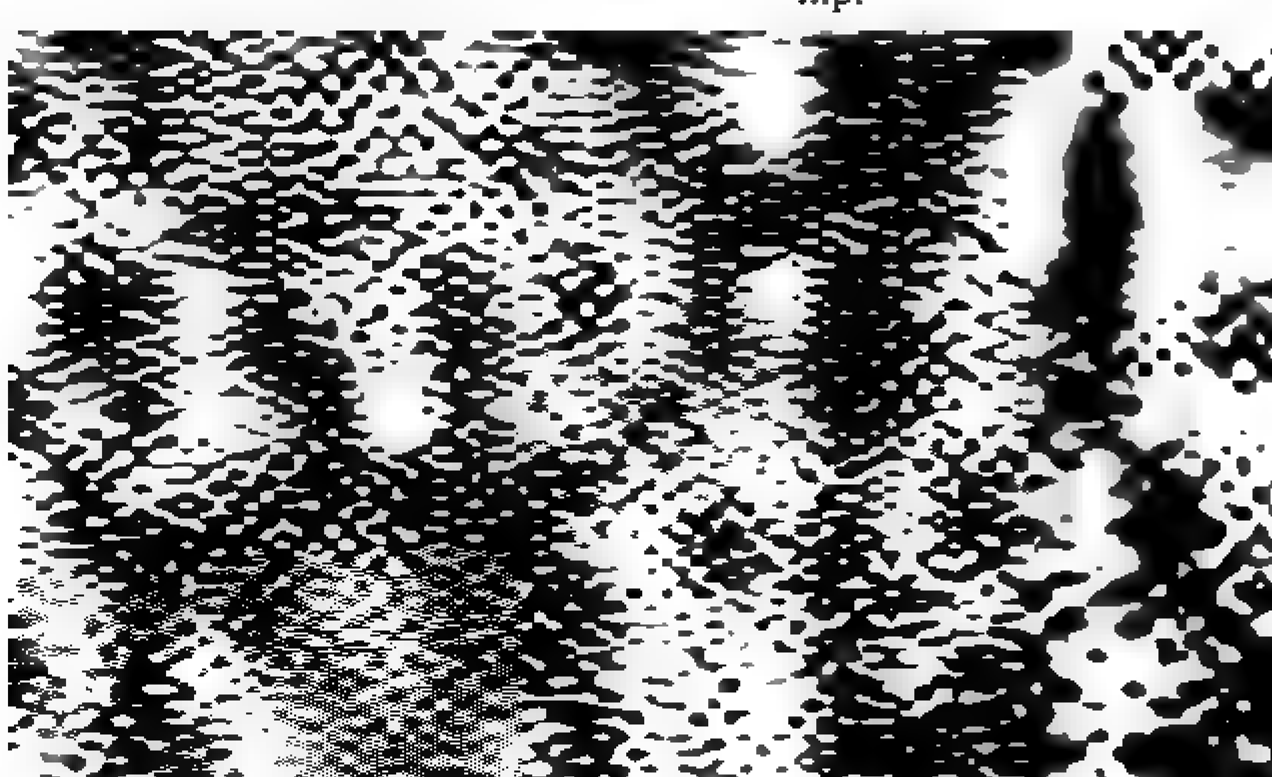


Fig. 495. Side View of Wisconsin Twelve.

WOLSELEY

The Wolseley Tool and Motor Car Co., Ltd., Adderley Park, Birmingham, England, built several air-cooled and water cooled eight-cylinder Vee type engines; beginning about 1907 with their own designs and later adding the Renault and Maybach, and during the war building the Hispano-Suiza engines.

50-h.p. The first Wolseley water-cooled eight-cylinder Vee type engine was rated at 50 h.p., and said to develop 54 h.p. at 1350 r.p.m. The bore was 3.75 in., the stroke 5 in., and the total displacement 441.76 cu. in. The fuel consumption was reported to be .726 lbs. per h.p-hr., and the oil consumption .28 lbs. per h.p-hr. The weight was stated to be 300 lbs., or 6 lbs. per rated h.p.

60-h.p. The next development was the 60-h.p. water-cooled model of 3.75 bore, 5.5 in. stroke, and 485.93 cu. in. total displacement. Some of these engines were fitted with a 15 lb. flywheel and said to weigh 366 lbs. Others were reported to weigh 294 lbs., or 4.9 lbs. per rated h.p.

The cylinders were made in pairs from cast-iron and fitted with sheet-aluminum water jackets held in place by screws.

Fig. 496. The Wolseley 60-h.p. Engine.

The side-by-side valves in the "L" head cylinders were operated directly by tappets from a camshaft in the Vee. The crankshaft was carried in three plain bearings, and the connecting rods were arranged side by side upon the crankpins.

These engines were built in both geared and direct drive types. Ignition was provided by an eight-cylinder Bosch magneto. The cooling water and the oil were circulated by pumps of the gear type.

Fig. 497. The Wolseley 75-h.p. Engine.

75-h.p. The 75-h.p. air-cooled engine, produced in 1913, was provided with water-cooled exhaust valve cages, a special radiator being fitted on the engine for cooling the water. The normal engine speed was 1800 r.p.m; the propeller was driven at half engine speed. The bore was 3.75 in., the stroke 5.5 in., and the total displacement 485.93 cu. in. The complete weight was reported to be 382.5 lbs., or 5.1 lbs. per rated h.p.

The steel cylinders had integral heads and cooling flanges. The valves stood vertically in the cylinder head and were operated through push rods and rockers from a camshaft in the Vee. The valves seated in removable cages that were secured

by ring nuts, the exhaust valve cage being made from welded steel and water-jacketed.

The crankshaft had three main bearings, and the connecting rods were placed side by side upon the crank-pins. The pistons were made of steel and fitted with four rings. The water was circulated to the exhaust valve cages by a gear pump. The lubricating system was of the force-feed type with oil circulated by gear pumps. Ignition was by a high-tension magneto.

90-h.p. A design similar to the 75-h.p. engine, also produced in 1913, was rated 90 h.p. at 1800 r.p.m. The bore was 4 in., the stroke 5.5 in., and the total displacement 552.88 cu. in. The weight was said to be 385 lbs., or 4.39 lbs. per rated h.p. The fuel consumption was reported to be .6 lbs. per h.p-hr.

Fig. 498. The Wolseley 120-h.p. Engine.

120-h.p. The 120-h.p. water-cooled engine was later made to develop 130 h.p. at 1200 r.p.m., and 150 h.p. at 1400 r.p.m. The bore was 5 in., the stroke 7 in., and the total displacement 1099.56 cu. in. The fuel consumption was stated to be .576 lbs. per h.p-hr., and the weight 640 lbs., or 5.3 lbs. per rated h.p.

Cast-iron cylinder heads containing cored water passages were screwed into the thin steel cylinder barrels, and water jackets from spun sheet-aluminum were attached to the head by a number of screws and made tight at the lower ends by packing joints which permitted free expansion.

The valves were inclined to the cylinder axis and operated by single centrally pivoted rockers and pull and push rods from plus and minus cams on the camshaft in the Vee. The exhaust valves had water passages around the ports and seated directly on the cast-iron cylinder heads. The inlet valves seated in screwed in removable cages. The clear diameter of both valves was 2.3 in.; the angle of the exhaust valve seats was 45 degrees, and the inlet valve seats were flat.

The four-throw crankshaft was carried in three plain bearings, and the big ends of the tubular connecting rods were placed side by side upon the crank-pins. The pistons were made of drawn steel with ribs under the crowned head, and were fitted with four wide rings, the upper two being of cast-iron and the lower two phosphor bronze.

Forced lubrication to the bearings was provided by gear pumps of the tandem type. A Wolseley two-jet carburetor was situated in the Vee, and dual ignition was supplied by Bosch magnetos. The cooling water was circulated by a gear pump.

90-h.p. A water-cooled design, similar to the 120-h.p. engine, was rated 90 h.p. at 1800 r.p.m. This engine was originally built with propeller reduction gears having a ratio of .5, although some were built with a direct driven propeller as were the 120-h.p. models. The bore was 3.75 in., the stroke 5.5 in., and the total displacement 485.93 cu. in. This engine was reported to weigh 405 lbs., or 4.5 lbs. per rated h.p.

"Python." The Wolseley "Python," constructed during the war, was the water-cooled eight-cylinder 90 degree Vee type Hispano-Suiza engine, rated at 150 h.p., with certain minor structural improvements. The bore was 120 mm. (4.72 in.), the stroke 130 mm. (5.51 in.), and the total displacement 716.72 cu. in.

Fig. 499. Longitudinal Section of Wolseley "Adder."

"Viper." The Wolseley "Viper," rated at 180 h.p., was the "Python" engine using higher compression pistons.

"Adder." The Wolseley "Adder" employed propeller reduction gears and was rated at 200 h.p. The design was otherwise almost identical to the "Python" engine.

Fig. 500. Transverse Section of Wolseley "Adder."

WRIGHT

The Wright engines are of historic interest as it was with the four-cylinder 30/35-h.p. model that the Wright Brothers achieved the first practical flight on December 17th, 1903. These engines were designed and built in their own shop and later were constructed by some of the early European airplane engine manufacturers.

Four-Cylinder. The Wright Brothers four-cylinder vertical water-cooled engine was rated 30/35 h.p. at 1200 r.p.m., and was said to deliver 39 h.p. at 1600 r.p.m. The bore was 4.375 in., the stroke 4 in., and the total displacement 240.52 cu. in. The weight was stated to be 180 lbs.

The individual cast-iron cylinders were jacketed only around the barrels with thin aluminum jackets and had no provision for head cooling. Inter-changeable valves stood vertically in the cylinder heads; the inlets operated automatically, and the exhausts by push rods and rockers from a camshaft in the crankcase. The connecting rods were of tubular section.

Fig. 501. The Wright Four-Cylinder Engine.

The crankshaft was fitted with a flywheel, and two sprockets which drove two propellers by chains at a .272 ratio. No carburetors were used; a small gear pump discharged the fuel into the open bell-mouthed end of the inlet pipe through a small jet orifice which regulated the amount of fuel to each cylinder. Lubrication was force-feed, a gear pump being driven from the camshaft. The cooling water was circulated by a centrifugal pump, and Mea magnetos furnished ignition.

Six-Cylinder. A six-cylinder vertical type, using the same cylinders and therefore having 360.78 cu. in. total displacement, was rated 50 h.p. at 1150 r.p.m. This engine was stated to weigh 230 lbs., or 4.6 lbs. per rated h.p.

Eight-Cylinder. The eight-cylinder 90 degree Vee type also employed the same cylinders as the four-cylinder engine and had a total displacement of 481.04 cu. in. This engine

was normally rated at 60 h.p., and drove the propeller at a higher speed than the four-cylinder model.

Six-Sixty. The Wright 6-60 model was a water-cooled six-cylinder vertical engine of 4.375 in. bore, 4.5 in stroke, and 405.9 cu. in. total displacement. It was rated 60 h.p. at 1400 r.p.m. and said to develop from 72 to 75 h.p. at 1560 r.p.m. The combined fuel and oil consumption was stated to be .67 lbs. per h.p-hr. The dry weight was approximately 300 lbs., or 5 lbs. per rated h.p.

Fig. 502. The Wright 6-60 Engine.

All but a few of the original design features of the four-cylinder engine were retained. The cylinders had integral water jackets of cast iron and were held down by long studs from lugs on the cylinder head. Two Zenith carburetors supplied three cylinders each. The overall dimensions were as follows: length 41 in., width 15 in., and height 27 in.

WRIGHT AERO

The Wright Aeronautical Corporation of Paterson, N. J., formerly the Wright-Martin Aircraft Corporation of New Brunswick, N. J., are the licensed American manufacturers of Hispano-Suiza engines which have more recently become known as the Wright engines.

The first attempt at manufacturing their own designs is the Model R, a nine-cylinder air-cooled radial engine, rated at 350 h.p., which is being developed for the Engineering Division of the Air Service. This engine has a 5.625 in. bore and a 6.5 in. stroke. Other designs progressing experimentally include a large water-cooled six-cylinder vertical engine for dirigible use, and a twelve-cylinder Vee type.

WRIGHT-BARIQUAND

Messrs. Bariquand and Marre of France built a copy of the original four-cylinder Wright engine which varied from the American prototype mainly in the mechanically operated inlet valves and auxiliary exhaust ports provided near the end of the piston stroke. This engine had a 112 mm. (4.41 in.) bore, 100 mm. (3.94 in.) stroke, and 240.72 cu. in. total displacement. It was rated 30 h.p. at 1300 r.p.m., and was said to weigh 211 lbs., or 7.03 lbs. per rated h.p.

ZEITLIN

The Zeitlin engines are variable-stroke air-cooled rotary types, designed by Mr. Joseph Zeitlin and constructed at the

Fig. 503. The Zeitlin Variable-Stroke Rotary Engine.

works of Messrs. W. H. Allen of Bedford, England. The first model had seven cylinders, and the modified designs were built with nine cylinders of 135 mm. (5.31 in.) bore to give 220 h.p. at 12,000 ft. altitude.

The fundamental point of difference between these engines and the conventional four-cycle rotary types is the eccentric sleeves upon the crankpin which produce working strokes of different length. The expansion stroke is 181 mm. (7.12 in.), the exhaust and compression strokes 203.5 mm. (8.01 in.), and the suction stroke 226 mm. (8.9 in.). After the working stroke of 181 mm., the exhaust stroke of 22.5 mm. greater length brings the piston almost to the top of the cylinder head and clears out practically all of the burnt gases. On the suction stroke the piston uncovers a port in the lower part of the cylinder wall for the admission of fresh gas from the crank chamber. The exhaust valve, which is located in the cylinder head, contains the spark plug.

The eccentrics are driven through gears at half speed in the direction of crank rotation, and so arranged that the balance of the engine is least affected. An altitude control arrangement is incorporated with the exhaust cam member.

SUPPLEMENT

ARGUS

The Argus Company experimented with an eight-cylinder Vee type water-cooled engine of 130 mm. (5.12 in.) bore, 140 mm. (5.51 in.) stroke, and 906.88 cu. in. total displacement, that was rated 250 h.p. at 1800 r.p.m. The propeller was driven through reduction gears at a 2 to 3 ratio, hence the normal speed was 1200 r.p.m.

The built-up steel cylinders were each fitted with two inlet and two exhaust valves that were operated through rockers from an overhead camshaft. The carburetor was situated in the Vee and drew its air from around the crankshaft bearings. The crankshaft was carried in five plain bearings, fuel was supplied to the carburetor by a pump, and pressure lubrication was furnished by a plunger pump.

BENZ

One of the war-time experiments of the Benz Company in Germany, with engines of larger power output, was a six-cylinder vertical water-cooled type developing 623 h.p. at 1400 r.p.m. The bore was 225 mm. (8.86 in.), the stroke 300 mm. (11.81 in.), and the total displacement 4368.52 cu. in.

Each cylinder was fitted with six valves and four spark plugs. During tests, the crankcase broke from severe vibration; and the cast-iron pistons, although sprayed from underneath by a current of oil, cooled very badly.

B. M. W.

The Bayerishe Motor Works of Munich, Germany, built an experimental six-cylinder vertical water-cooled engine, rated 400 h.p. at 1300 r.p.m. The bore and stroke were 180 mm. (7.09 in.), and the total displacement 1679.52 cu. in. During tests, the cylinders overheated and the power output was insufficient.

Classification of Conventional Types of Airplane Engines

WATER-COOLED FOUR-CYCLE ENGINES

	*
VERTICAL	
Four-Cylinder	99
Six-Cylinder	123
Eight-Cylinder	11
Inverted, Four-Cylinder	2
VEE	
Four-Cylinder	4
Six-Cylinder	3
Eight-Cylinder	115
Twelve-Cylinder	87
Sixteen-Cylinder	9
Thirty two-Cylinder	1
W	
Six-Cylinder	1
Nine-Cylinder	1
Twelve-Cylinder	4
Eighteen-Cylinder	7
Twenty four-Cylinder	1
DOUBLE VEE	
Sixteen-Cylinder	1
Y	
Twelve-Cylinder	2
X	
Eight-Cylinder	1
Sixteen-Cylinder	5
RADIAL	
Five-Cylinder	1
Six-Cylinder	1
Seven-Cylinder	1
Eight-Cylinder	1
Nine-Cylinder	6

*This represents the number of each particular type of engine referred to in the Airplane Engine Encyclopedia.

AIR-COOLED FOUR-CYCLE ENGINES

RADIAL	
Three-Cylinder	9
Five-Cylinder	7
Six-Cylinder	8
Seven-Cylinder	7
Nine-Cylinder	10
Ten-Cylinder	12
Eleven-Cylinder	1
Fourteen-Cylinder	4
Eighteen-Cylinder	2
Twenty-Cylinder	1
HORIZONTAL RADIAL	
Eight-Cylinder	3
HORIZONTALLY OPPOSED	
Two-Cylinder	17
Eight-Cylinder	3
Twelve-Cylinder	1
ROTARY	
Three-Cylinder	2
Five-Cylinder	7
Six-Cylinder	2
Seven-Cylinder	29
Nine-Cylinder	26
Ten-Cylinder	3
Eleven-Cylinder	6
Fourteen-Cylinder	7
Eighteen-Cylinder	8
Thirty six-Cylinder	1
HORIZONTAL ROTARY	
Three-Cylinder	1
Five-Cylinder	1
BARREL ROTARY	
Three-Cylinder	1
Five-Cylinder	1
Six-Cylinder	1
Seven-Cylinder	2
Ten-Cylinder	1
DIFFERENTIAL ROTARY	
Nine-Cylinder	1
Eleven-Cylinder	1

DOUBLE ROTARY

Six-Cylinder	4
Ten-Cylinder	2
Fourteen-Cylinder	1
Eighteen-Cylinder	1

WATER-COOLED TWO-CYCLE ENGINES

VERTICAL

Two-Cylinder	1
Three-Cylinder	4
Four-Cylinder	10
Six-Cylinder	8
Eight-Cylinder	1

VEE

Four-Cylinder	2
Six-Cylinder	1
Eight-Cylinder	1
Twelve-Cylinder	2

RADIAL

Six-Cylinder	3

AIR-COOLED TWO-CYCLE ENGINES

VERTICAL

Four-Cylinder	2

VEE

Four-Cylinder	1

RADIAL

Five-Cylinder	1
Six-Cylinder	1
Ten-Cylinder	1

ROTARY

Two-Cylinder	2
Six-Cylinder	4
Seven-Cylinder	1

Index

WATER-COOLED FOUR-CYCLE ENGINES

VERTICAL

SIX CYLINDER

EIGHT-CYLINDER

INVERTED, FOUR-CYLINDER

VEE

FOUR-CYLINDER

SIX-CYLINDER

EIGHT-CYLINDER

TWELVE-CYLINDER

DOUBLE VEE

Y

X

RADIAL

HORIZONTAL RADIAL

HORIZONTALLY-OPPOSED

DOUBLE-CRANKSHAFT

BARREL

AIR-COOLED FOUR-CYCLE ENGINES

VERTICAL

FOUR-CYLINDER

SIX-CYLINDER

UPRIGHT, FOUR-CYLINDER

VEE

TWO-CYLINDER

FOUR-CYLINDER

EIGHT-CYLINDER

SIX-CYLINDER

SEVEN-CYLINDER

NINE-CYLINDER

TEN-CYLINDER

ELEVEN-CYLINDER

VEE

RADIAL

AIR-COOLED TWO-CYCLE ENGINES

VERTICAL

VEE

RADIAL

ROTARY

WATER AND AIR-COOLED ENGINES

UNCONVENTIONAL TYPES OF AIRPLANE ENGINES